



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>

General Library
—OF—
UNIVERSITY OF MICHIGAN.

PRESENTED BY

R. B. Smith

Oct 27

1897

QD

45

M787

LABORATORY MANUAL

66811

OF

ELEMENTARY CHEMISTRY

BY

J. ¹⁶⁴MONTGOMERY, PH.D.

AND,

R. B. SMITH

ANN ARBOR HIGH SCHOOL.

PUBLISHED BY GEORGE WAHR

ANN ARBOR, MICH.

1897.

COPYRIGHT BY
GEORGE WAHR
1897

THE INLAND PRESS
ANN ARBOR, MICH.

PREFACE.

This little book is intended for a laboratory guide and should be used in connection with a good text-book, or, a course of lectures fully illustrated by experiments.

It calls for no work that may not be done by the average high school pupil. As a matter of fact nearly all of these experiments have been performed by such pupils many times over; one of the authors having used most of them for twelve or fifteen years.

The explanations may appear to be unnecessarily minute. Experience teaches, however, that it is almost impossible to be too careful with the beginner.

The attempt has been made to throw the pupil more and more upon his own resources as he becomes more familiar with chemical manipulation.

The experiments on the metals are intended to acquaint the pupil with the properties of important metals and some of their compounds. The tables are not intended for complete analysis, for which they are scarcely fitted, but rather, to be the basis of a series of exercises which will lead the pupil, in some measure, to comprehend the methods of analytical chemistry. Indeed, the authors doubt the propriety of attempting to teach chemical analysis in high schools, but, experience has shown them that some such work has an excellent effect in creating interest and enthusiasm.

A few problems in quantitative analysis have been inserted to give the learner an idea of accurate work.

In most cases a few of the commoner metals and their important compounds will be all that can be studied. However, the extent of this kind of work will depend upon the time and laboratory facilities at the disposal of the instructor.

10459 E.D.P.
Rec'd 8-12-33 HEN

A lack of uniformity of treatment will be observed. This is, in a sense, intentional. The arrangement of matter and the insertion or omission of formulæ, etc., has all been made to depend upon what seemed best for the pupil.

The sources of materials used will be recognized by any one somewhat familiar with chemical literature. The special form of some of the experiments was devised long before they appeared in any text-book.

The figures and tables have been selected and modified to suit our purposes and are found in many text-books published during the last fifteen or twenty years. For the tables in analysis, however, the works of Prescott and Johnson, Will, and Fresenius have been most frequently consulted. In some of these but slight modification has been made.

Frequently the atomic weight to the nearest whole number, or large decimal, only, has been given. The accurate determinations will be found in the table.

Rules to guide the pupil in the laboratory are sometimes inserted in manuals like this. We have omitted everything of this kind, believing that the competent teacher can prepare directions that will suit his purposes better than any one else.

We wish to acknowledge our indebtedness to many friends for suggestions, proof reading and other assistance, so kindly rendered, while the press work was in progress. We shall be glad to receive suggestions and corrections from any and all, that errors may be eliminated from future editions should there be such.

Hoping that our book may be helpful to teacher and pupil, we commend it to all educators who believe that contact with the thing is the only way to gain real scientific knowledge.

ANN ARBOR, MICH., 1897.

TABLE OF COMMON ELEMENTS.

NAME.	SYMBOL.	H=1.	O=16	DISCOVERY.	DISCOVERER.
Aluminum.....	Al	26.91	27.11	1827	Wöhler
Antimony.....	Sb	119.52	120.43	15th century	Basil Valentine
Argon.....	A	?	?	1894	{ Rayleigh and Ramsay
Arsenic.....	As	74.44	75.10	1694	Schröder
Barium.....	Ba	136.39	137.43	1808	Davy
Bismuth.....	Bi	206.54	208.11	15th century	Valentine
Boron.....	B	10.86	10.95	1808	{ Gay Lussac and Thenard
Bromine.....	Br	79.34	79.95	1826	Balard
Cadmium.....	Cd	111.10	111.95	1817	Stromeyer
Calcium.....	Ca	39.76	40.07	1808	Davy
Carbon.....	C	11.92	12.01	Ancient
Chlorine.....	Cl	35.18	35.45	1774	Scheele
Chromium.....	Cr	51.74	52.14	1797	Vauquelin
Cobalt.....	Co	58.49	58.93	1742	Brandt
Copper.....	Cu	63.12	63.60	Ancient
Fluorine.....	F	18.91	19.06	1886	Moissan
Gold.....	Au	195.74	197.23	Ancient
Helium.....	He	?	?	1895	Ramsay
Hydrogen.....	H	1.00	1.008	1766	Cavendish
Iodine.....	I	125.89	126.85	1811	Courtois
Iron.....	Fe	56.60	56.02	Ancient
Lead.....	Pb	205.36	206.92	Ancient
Magnesium.....	Mg	24.10	24.28	1808	Davy
Manganese.....	Mn	54.57	54.99	1774	Gahn
Mercury.....	Hg	198.49	200.00	Ancient
Nickel.....	Ni	58.24	58.69	1750	Cronstedt
Nitrogen.....	N	13.93	14.04	1772	Rutherford
Oxygen.....	O	15.88	16.00	1774	Priestly
Phosphorus.....	P	30.79	31.02	1669	Brandt
Platinum.....	Pt	193.41	194.89	1750	Watson
Potassium.....	K	38.82	39.11	1807	Davy
Selenium.....	Se	78.42	79.02	1817	Berzelius
Silicon.....	Si	28.18	28.40	1822	Berzelius
Silver.....	Ag	107.11	107.92	Ancient
Sodium.....	Na	22.88	23.05	1807	Davy
Strontium.....	Sr	86.95	87.61	1808	Davy
Sulfur.....	S	31.83	32.07	Ancient
Tin.....	Sn	118.15	119.05	Ancient
Zinc.....	Zn	64.91	65.41	16th century	Paracelsus ?

ENTS.

OMIC WEIGHT 1.
(builder).

ator, from a wide
the bottle snugly
nel tube (A) and



by heating in the
Take care that
tly.

ated zinc (Zn) to
nel pour dilute
gins.

part of concen-
Always pour sul-

furic acid into water, but *never* water into the acid, because so much heat is developed in the latter process that acid may be thrown out of the vessel by production of steam).

An evolution of gas at once begins and it may be collected, thus: Fill a bottle full of water and cover with a glass slip, then invert in a vessel containing water. On removing the glass slip the bottle remains full. Conduct the gas through the delivery tube into this bottle and the water will be displaced by the gas. In this way collect several bottles of gas and after covering with glass slips set them aside for future use. This process is called "collection by displacement of water."

II. Collect one or two bottles of the gas by placing the end of the delivery tube in an inverted bottle. Such a process is called "collection by upward displacement." What must be the weight of hydrogen as compared with air to make such a process possible?



III. Attach a clay pipe to the generator by means of a rubber tube. Make soap bubbles and set them free. What do they do? Is the gas in them heavier than air? Blow some bubbles from the lungs and set them free. Note the difference between these and those filled with hydrogen. Ignite some hydrogen bubbles when they are some distance away from the generator. Now collect a test tubeful of gas by displacement of water and ignite. Does the hydrogen explode? If it does there is still air mixed with the gas. Allow the gas to generate for a minute or two and test again. When the hydrogen is perfectly free from air perform experiment IV.

NOTE.—To make soap bubbles use a solution of soap made as follows. Cut about four ounces of pure

NONMETALLIC ELEMENTS.

castile or palm oil soap into thin shavings and place them in a quart bottle. Fill with distilled water and shake until a saturated solution of soap is formed. Allow to stand for a short time and you should have a perfectly clear solution. If this is not the case shake up again with more water. Now to two volumes of soap solution add one volume of pure concentrated glycerin and a solution is obtained which makes splendid bubbles. Ivory soap has been used with much success in making this solution.

IV. Replace the delivery tube with a jet tube, i. e., a glass tube drawn out to a fine point. If you are sure that no air is present light the jet of gas. *Be very careful in this experiment so that dangerous explosions may be avoided.* A mixture of air and hydrogen is very explosive.

V. Hold a large tube or broken retort stem over the little burning jet, moving tube up and down. Note the singing noise. Try several tubes. Explain.

VI. Thrust a burning match into a bottle of hydrogen. Will the gas burn? Will it support combustion? Note color of the flame when first lighted, then after it has been burning some time. Is the flame hot?

Next invert a small bottle of gas under a burning match. Does the gas burn? What forces the gas out of the bottle?

VII. Hold an empty bottle inverted and invert another filled with hydrogen under it. Test the gas in each bottle. What change has taken place? What other experiments show the same properties of hydrogen?

VIII. To make a hydrogen gun. In the side of a baking powder can punch a hole near the bottom. Fill the can with hydrogen, over water, holding the thumb over



full bubbles will
cover on the can,
the thumb and
the gas is burned.
when the exper-

mixture of air and
ation $2H$ (hydro-

filling the gun with
en. Is there any
the caution under

WATER.

in pan with water
be filled with water



ry forceps hold a
(Na) under the
lapped the sodium

in dry tissue paper. As soon as the evolution of gas stops test the contents of the bottle with a flame. What gas has been formed?

The reaction is as follows. H_2O (water) + Na (sodium) = H (hydrogen) + NaOH (sodium hydroxid).

Caution.—Sodium is a metal which combines very readily with water with evolution of hydrogen. The reaction is almost explosive, but if small bright pieces of the metal are used there is little danger. Before use, therefore, always see that the piece of metal is bright and clean. Sodium must be kept under benzine to prevent it from combining with the moisture of the air.

REACTIONS FOR FORMATION OF HYDROGEN.

Zn (zinc) + H_2SO_4 (sulfuric acid) = 2H (hydrogen) + ZnSO_4 (zinc sulfate).

Many other metals, such as iron (Fe) magnesium (Mg), etc., give hydrogen when dissolved in acids as sulfuric acid or hydrochloric acid (HCl .)

HALOGEN GROUP.

Cl (chlorin), Br (bromin), F (fluorin), and I (iodin). The word halogen means salt builder from the fact that the halogens combine with metals to form salts.

CHLORIN.

SYMBOL CL.

ATOMIC WEIGHT 35.40.

Name from Chloros (green).

I. PREPARATION.—To a small quantity of manganese dioxid in a test tube add 5 or 6 cc. hydrochloric acid (HCl) and heat gently. Note the odor and color of the escaping gas. Reaction. MnO_2 (manganese dioxid) + 4HCl = MnCl_2 (manganese chlorid) + $2\text{H}_2\text{O}$ + 2Cl (chlorin).

paper in the
colored cloth or
that takes place
does chlorine

g matter which
potassium hy-
mus paper on
due by moisten-
your ammonia

in. Is the gas
from one tube

in water. What
the solubility of

chlorate (KClO_3)



oxid) + 2 Cl.
the gas. Does

TO MAKE CHLORIN IN QUANTITY.

Mix well five parts manganese dioxid with eleven parts of common salt. Place in a flask fitted with delivery tube and treat with a dilute solution of sulfuric acid, one part water to two parts acid. Collect the gas by downward displacement, i. e., by conducting the gas into empty jars standing upright as in the figure. It cannot be collected over water as hydrogen was. Why?

Reaction. $\text{MnO}_2 + 3 \text{H}_2\text{SO}_4 + 2 \text{NaCl}$ (salt or sodium chlorid) = 2NaHSO_4 (sodium acid sulfate) + MnSO_4 (manganese sulfate) + $2 \text{H}_2\text{O} + 2 \text{Cl}$.

BROMIN.

SYMBOL BR.

ATOMIC WEIGHT = 79.34.

Name from Bromos (a stench).

I. PREPARATION.—Pulverize two or three crystals of potassium bromid and mix well with an equal quantity of manganese dioxid. Add about 5 cc. H_2SO_4 and heat gently. Dilute the acid by mixing one part of acid with five of water.

II. Note the color of gas, then very *carefully* its odor. The odor of bromin is, as indicated by the name, very unpleasant so be careful not to inhale too much. Test the gas with a burning splint. Test as you did chlorin with a piece of blue litmus paper and with colored cloth or paper. Is there any similarity in the action toward dyes between chlorin and bromin?

III. Dissolve a few crystals of potassium bromid (KBr) in water and add to the solution a few drops of chlorin water. Note change in color. Bromin has been formed according to the reaction $\text{KBr} + \text{Cl} = \text{KCl}$ (potassium chlorid) + Br.

1
2
3
4

5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100

101

Now add a few drops of carbon disulfid (CS_2) to the solution and shake well. Put your thumb over the end of the test tube and shake up and down violently. Note change in color of the carbon disulfid.

Make a thin starch paste and add a little to a solution containing bromin. Note change in color after shaking. Compare with CS_2 test. These two tests are most frequently used for bromin in qualitative analysis.

IV. Invert the tube of experiment I. in water. Is bromin soluble?

REACTION FOR BROMIN.

$2 \text{KBr} + \text{MnO}_2 + 3 \text{H}_2\text{SO}_4 = 2 \text{KHSO}_4$ (potassium acid sulfate) $+ \text{MnSO}_4 + 2 \text{H}_2\text{O} + 2 \text{Br}$. Compare with the equation for chlorin.

IODIN.

SYMBOL I.

ATOMIC WEIGHT 125.89.

The name comes from a Greek word meaning violet colored.

I. PREPARATION.—Heat a few crystals of potassium iodid mixed with MnO_2 and H_2SO_4 just as you did in the preparation of bromin. Dilute the acid before use. Write the equation.

II. Test the gas with a burning splint. With blue litmus paper. Note the odor and color of iodin vapor. Is the vapor heavier or lighter than air? Is iodin ordinarily a solid, liquid or gas?

III. Invert the tube of experiment I. in water. When the tube is cool examine the sides for crystals of iodin.

What do you know about the relative solubility of Cl, Br and I.

IV. Make a solution of potassium iodid in water. Add chlorin water and test with carbon disulfid and starch paste. Compare with bromin.

D.

WEIGHT 36.4.

and is found by
 ing up the com-

ams of sodium
 s in the figure,

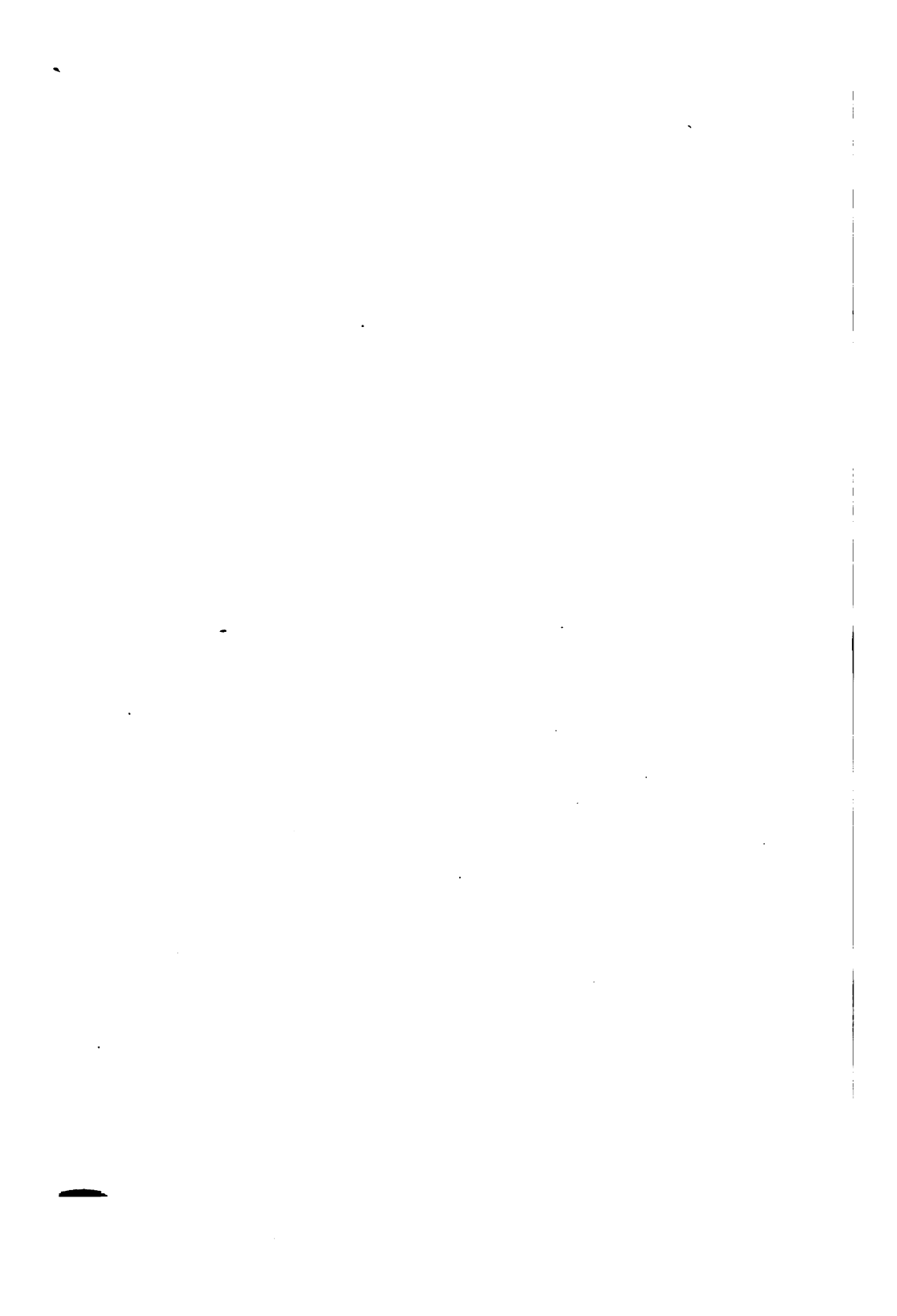


absolutely neces-
 collected be dry;
 the clinging to the
 obtained.

HCl.

acid sulfate) +

SO₄ (normal or
 eight inch test
 shown in the cut.
 of glass tube in
 as soft remove



Allow to cool, break and you roughly a medium hole and insert flask with HCl. Tell when the rod dipped in be formed when dia.

the end of the solution. In a



Indicated is very passing the gas into minutes.

add a drop of happens?

(silver chlorid) +

of lead acetate

.

.

.

.

.

.

.

.

Reaction. $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2 + 2 \text{HCl} = \text{PbCl}_2$ (lead chlorid) + $2 \text{HC}_2\text{H}_3\text{O}_2$ (acetic acid).
WHITE

Repeat with mercurous nitrate.

Reaction. $\text{HgNO}_3 + \text{HCl} = \text{HgCl}$ (mercurous chlorid) + HNO_3 .
WHITE

NOTE.—In all these experiments a single drop will suffice. Never use large quantities of reagents unless so directed.

VI. Repeat experiment V. with a solution of NaCl in water. Write out all the reactions.

VII. Solubility of metals in hydrochloric acid.

Dissolve a little piece of iron wire in the acid from your table. Is a gas given off? Test with a burning splint. What is it? Repeat with Zn.

In a small evaporating dish evaporate these solutions to dryness. Note what you have left from each solution after evaporation. You have two salts, one of iron and one of zinc. Hydrochloric acid dissolves metals to form salts. Not all metals are soluble in HCl, though many are.

VIII. Hold a green leaf in HCl gas.

IX. Invert the tube or flask of experiment I. in water. Which is more soluble, the halogen family or this compound of a halogen with hydrogen?

X. Put some gold leaf in a test tube and add HCl from the table. Note effect.

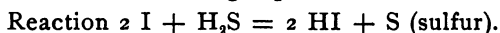
XI. Put another piece in a second tube and treat with nitric acid (HNO_3). Note effect.

Mix the two and note change.

A mixture of nitric and hydrochloric acids is called Aqua Regia. Compare with reaction for dissolving mercury in Aqua Regia.

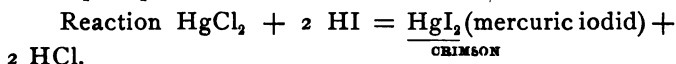
HYDRIODIC ACID.

I. PREPARATION.—Put two or three crystals of iodine in a test tube, then add water till it is half full. From a Kipp's apparatus run in hydrogen sulfid (H_2S) until the solution becomes colorless. Boil to free from excess of H_2S , i. e., boil till the liquid no longer smells of the gas. You now have a weak solution of hydriodic acid containing sulfur in the form of a fine powder. After standing a moment the sulfur will settle and the clear solution may be used for the following experiment.

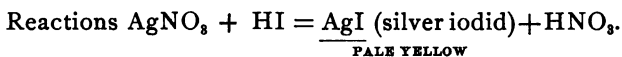


For description of Kipp's apparatus see hydrogen sulfid.

II. Add a few drops of the hydriodic acid solution to a solution of mercuric chlorid (HgCl_2). Note the color of the precipitate.



Try same with a solution of silver nitrate, of lead acetate.



III. Try II. with a solution of potassium iodid and write out all the reactions.

HYDROFLUORIC ACID.

Hydrofluoric acid is an extremely volatile and poisonous acid. In working with it be very cautious, always work under a hood and never inhale any of the fumes. A hood is a cupboard connected with a chimney, so that all noxious vapors are drawn off into the air above the building. It is well always to test a hood before use by light-



ing a match, holding inside the hood and noticing by the flame and smoke if the draught is good.

I. PREPARATION. —Etching experiment.

Cover a glass slip on one side with wax or paraffin. Cut in the wax with a pin or some sharp pointed instrument the design that you wish engraved. In a leaden dish under the hood place about four grams of powdered calcium fluorid (CaF_2) and add strong sulfuric acid so as to make a thin paste. Warm very gently and cover the dish with the piece of glass, wax side down. After standing about half an hour the design you have drawn will be etched on the glass. Scrape off the wax and clean glass thoroughly.

Reaction. $\text{CaF}_2 + \text{H}_2\text{SO}_4 = 2 \text{HF}$ (hydrofluoric acid) + CaSO_4 (calcium sulfate).

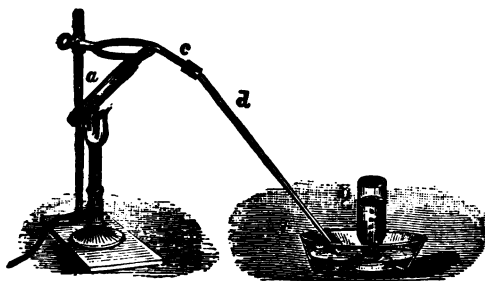
Compare with the reaction for hydrochloric acid.

OXYGEN.

SYMBOL O.

ATOMIC WEIGHT 16.

I. PREPARATION. —Pulverize one-quarter of a test tubefull of potassium chlorate. Add half as much man-



ganese dioxid and mix thoroughly. Prepare a large test tube with a tight fitting cork and delivery tube as shown in the figure. Place the mixture in the tube and arrange to collect the gas over water.

careful not to
the place. It is
by flame of the
This deposits a



hollowing out a
p with a knife.
wire about the
In the deflagra-
on place a little
sulfur and ignite
Bunsen burner
just in a bottle of
as in the figure.
te the color of
ne and the odor
duct formed.

Reaction sulfur S
= SO_2 (sulfur

Place a glow-
e of charcoal in
xygen. Carbon
 $\text{C} + 2 \text{O} = \text{CO}_2$

VI. Many substances which are incombustible under ordinary conditions burn easily in oxygen. Coil a fine iron wire in the form of a spiral. Warm one end slightly and dip in sulfur. Ignite and thrust in a bottle of oxygen. The iron takes fire and burns brilliantly. It is always necessary to have about an inch of water in the bottom of the bottle. Why?

Reaction. $3 \text{ Fe (iron)} + 4 \text{ O} = \text{Fe}_3\text{O}_4$ (ferric oxid).

VII. Dry a piece of phosphorus carefully with blotting paper and place in the deflagrating spoon. Lower into a bottle of oxygen and ignite with a warm wire.

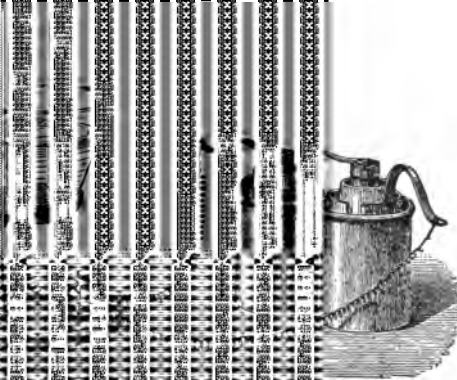
In handling phosphorus extreme care must be used, as it takes fire very easily. *Never* handle it with your fingers but *always* with pincers.

WATER.

COMPOSITION OF WATER PROVED BY EXPERIMENT.

I. Crack off the bottom of a medium sized, wide-mouthed bottle or glass jar. This may be done by scratching the glass with a file, then touching the crack with a red hot glass rod or piece of iron. The bottle will break parallel to the first file mark. Close the neck with a close fitting cork, through which two platinum wires pass. Put tips on these wires of small pieces of platinum foil about one-half inch in length by one-quarter wide. Invert the apparatus thus made, support it in some way and fill two-thirds full of water; add two or three cc. of H_2SO_4 and connect the outer ends of the platinum wires with two potassium dichromate or other good cells. Over the platinum tips invert two graduated tubes filled with water. After connecting with the cells bubbles of gas will form on the platinum tips and rise in the tubes. After several cubic centimeters of gas have collected note the

two tubes. Test
 gases? Of which
 gas came off at



copper oxid (CuO) in
 (copper). Water
 on given. In the
 a bulb has been



is a bottle filled
 been soaked in
 removes all moisture
 with calcium

are passing over
 ned by treating
 hydrogen may be
 id tube before

WEIGHT 31.98.

sulfur under the
 lf full of sulfur
 as a light yellow
 color changes

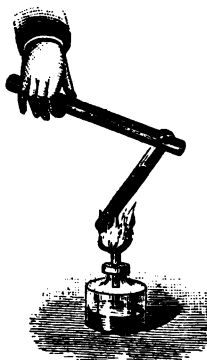


the above experi-
 two grams of
 ms of fine iron
 lower end of the
 remove from the
 ff. Note what

remains in the tube after heating. Does it look like sulfur? Like iron filings? Break the tube and take out a little piece of the sulfid you have made and treat it with dilute hydrochloric acid in a small test tube. Note the odor of gas generated. What does it smell like? The gas is hydrogen sulfid.

Reaction. $\text{Fe} + \text{S} = \text{FeS}$ (ferrous sulfid).

III. Burn a very small quantity of sulfur in the air on a deflagrating spoon. Note the color of flame and odor of gas formed. What does the gas smell like? It is called sulfur dioxid and is made by a direct union of sulfur and the oxygen of the air.



Reaction. $\text{S} + 2 \text{O} = \text{SO}_2$.

IV. Light a quantity of sulfur in a deflagrating spoon and lower into a large bottle. When the sulfur stops burning what does the bottle contain? Lower a moist colored flower into the bottle and note change in color. Do you know of any way in which this property of sulfur dioxid is put to practical use?

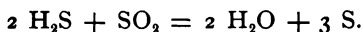
V. Prepare dilute sulfuric acid by putting about three drops of acid in three cc. of water. Place the bleached flower in this solution. Does the color change again?

VI. Suspend a moist wheat straw in a bottle of SO_2 as in IV.

Sulfur dioxid takes up oxygen from water and gradually changes to sulfuric acid. At the same time it sets free hydrogen and this nascent hydrogen by its action upon the coloring matter either destroys or changes the color. Such a process is called reduction while an action thguorb about by oxygen is called oxidation.

1

VII. Sulfur is probably formed in nature as in the following experiment: H_2S (hydrogen sulfid) and SO_2 (sulfur dioxid) are two gases always found in volcanic regions. When they are brought together they form free sulfur and water according to the equation.



Conduct hydrogen sulfid from a Kipp's apparatus (see description under hydrogen sulfid) into an empty bottle and at the same time sulfur dioxid from a generator (see sulfuric acid manufacture). A deposit of sulfur is formed on the bottom and sides of the bottle.

HYDROGEN SULFID.

I. PREPARATION.—Fit a six inch test tube with a cork through which passes a jet tube with the small end out. In the test tube place a small piece of ferrous sulfid (FeS) and fill half full of water. Add several drops of sulfuric acid and soon an evolution of gas will begin. Light the gas at the end of the delivery tube. What is formed? Compare odor of gas formed by burning with that of the original gas. Test the hydrogen sulfid with moist blue litmus. From this test how would you class H_2S among the compounds you have already studied?

Equation. $\text{FeS} + \text{H}_2\text{SO}_4 = \text{FeSO}_4$ (ferrous sulfate) + H_2S .

Hydrochloric acid may be used as well as sulfuric, so try to write the equation.

This same method is used to prepare the gas in quantity, only a more complex piece of apparatus is used. The figure represents the apparatus used, which is designated as Kipp's apparatus from its inventor. It consists of three large bulbs of glass, the two lower bulbs (b) and (c) being joined together while (a) having a long stem like

extends nearly
the apparatus to
first introduce a
through the opening
bulb (b) half
The glass wool
into the lower



and from there
ended for use in

under a hood as
should never be

is into test tubes
ate (CuSO_4), (b)
($\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$),
in each case.

Reactions. $\text{CuSO}_4 + \text{H}_2\text{S} = \text{CuS}$ (copper sulfid) + H_2SO_4 .

$\text{HgCl}_2 + \text{H}_2\text{S} = \text{HgS}$ (mercuric sulfid) + 2HCl .

$\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2 + \text{H}_2\text{S} = \text{PbS}$ (lead sulfid) + $2 \text{HC}_2\text{H}_3\text{O}_2$.

$\text{As}_2\text{O}_3 + 3 \text{H}_2\text{S} = \text{As}_2\text{S}_3$ (arsenic sulfid) + $3 \text{H}_2\text{O}$.

III. Pass hydrogen sulfid into a solution of ferric chlorid (FeCl_3). It is reduced to ferrous chlorid and sulfur is precipitated.

Reaction. $2 \text{FeCl}_3 + \text{H}_2\text{S} = 2 \text{HCl} + 2 \text{FeCl}_2$ (ferrous chlorid) + S .

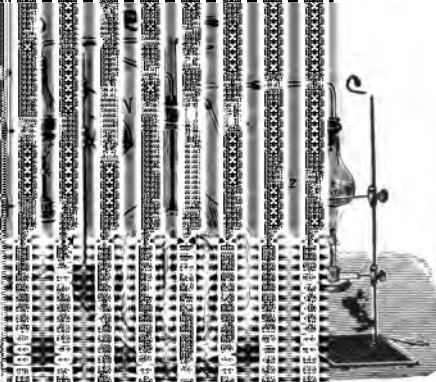
IV. Pass hydrogen sulfid through strong sulfuric acid. What is formed? Collect the precipitate if one is formed and ignite on a small piece of wood. Note the odor and color of flame of the burning precipitate. What was the precipitate? Try the same with a mixture of nitric and hydrochloric acids.

V. Give all possible means at your disposal of detecting (a) SO_2 , (b) H_2S and (c) O .

SULFURIC ACID.

I. PREPARATION.—Sulfuric acid may be made on a small scale as follows. A large glass globe A is closed with a cork containing five glass tubes as shown in the figure. Four of these tubes reach nearly to the bottom of the globe, while one serves as an escape valve F. One of the tubes is connected with a flask D containing strong sulfuric acid and copper turnings for the generation of sulfur dioxid. Another, B, contains copper turnings and dilute nitric acid 1-3 for the generation of nitric oxid and the last C contains water for the formation of steam. The tube marked E is used to renew the supply of air from time to time during the process.

at D. When this
 into B (one part
 to enter the large
 in C almost boil-
 the main thing is



sulfur dioxide nor
 reactions which take
 place are as follows.
 (ferrous sulfate) + SO_2

$3\text{Cu}(\text{NO}_3)_2$ (cop-
 per nitrate).

$= \text{NO}_2$ (nitrogen

dioxide) + NO .

(nitric

acid).

It is assumed to be much

more than the above is a

large quantity of sulfuric acid

is renewed in the

globe A whenever the red fumes of nitrogen dioxid can no longer be seen.

II. After some acid has collected in the bottom of the receiver allow the apparatus to cool and test a small quantity with barium chlorid (BaCl_2). Note the precipitate. Try the same with dilute acid from your table. Are the two results the same?

Reaction. $\text{BaCl}_2 + \text{H}_2\text{SO}_4 = \text{BaSO}_4$ (barium sulfate) + 2 HCl.

III. To a small quantity of sugar in a test tube add concentrated sulfuric acid. Note color of sugar. Try the same with a match stub.

IV. To a small quantity of water in a test tube add sulfuric acid. Note change in temperature of the water. Sulfuric acid has a great affinity for water, and it is on this that the blackening of the sugar and the wood depends. These substances are organic bodies composed of oxygen, hydrogen and carbon. The acid takes away some of the oxygen and hydrogen and leaves the carbon.

NITROGEN.

SYMBOL N.

ATOMIC WEIGHT 14.

I. PREPARATION.—In a slice of cork about half an inch thick and smaller than the mouth of a large bottle or jar, make a cavity and line with plaster of Paris. Make a paste by mixing the plaster with a little water. When the plaster is dry, place a dry piece of phosphorus about as large as a pea on the cork, float it on water in a basin filled with water, ignite the phosphorus with a hot wire and invert the bottle over it.

Reaction. $2 \text{ P (phosphorus)} + 5 \text{ O} = \text{P}_2\text{O}_5$ (phosphorus pentoxid).

$\text{P}_2\text{O}_5 + 3 \text{ H}_2\text{O} = 2 \text{ H}_3\text{PO}_4$ (phosphoric acid).

of the phosphorus.
 may not all be con-
 air for combustion?
 phosphorus pentoxid.

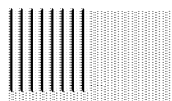


Why do we need any
 five or ten minutes,
 Is the nitrogen as
 ment I-II with blue
 See the equations

out a gram of am-
 odor.
 (Ca(OH)₂) in your
 orid and lime and
 ice?

dry test tube and
 first smoked the

chlorid) + Ca(OH)₂
 rid) + 2 NH₃ (am-



aked lime (CaO).
formed. Write
case of a very
salt heated with
(KOH) or sodium

with HCl to the
ponia. What is

us paper in the
m a similar one

NH_4Cl in a mor-

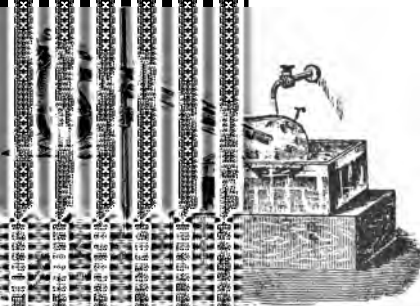


bottle or test tube
urn or support

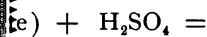
pt of about 250
of pulverized
trate (NaNO_3).



five cc. of strong
on a piece of
securely and heat
by allowing them



the liquid in the
the experiment.
of acid that dis-



and the tempera-
thus:

NO_3 and normal

in an iron spoon
acid you have

oxidizing agent
combustion.

1

—

III. Dip a piece of woolen cloth into dilute nitric acid from the table. After standing a short time wash the cloth thoroughly. Note its color.

IV. Place a piece of copper foil (Dutch leaf) in a test tube and pour on a little nitric acid.

V. Cover a piece of iron or brass with paraffin. Write upon it with the point of a file or pin; pour a little nitric acid upon the writing and let it stand until bubbles are formed along the lines of writing. Wash, remove the paraffin. Note the result.

VI. Place a cubic centimeter of indigo solution in a test tube and pour on nitric acid. This is often used as a qualitative test for nitric acid.

VII. Into dilute nitric acid drop a crystal of ferrous sulfate (FeSO_4). Do not shake. Note color around the crystal. Try the same with five cc. of H_2O and one cc. of HNO_3 .

VIII. Brown ring test for nitric acid and nitrates.

Dissolve a little KNO_3 or NaNO_3 in water. Add a little ferrous sulfate solution. Incline the test tube and allow a little strong H_2SO_4 to run down the side. Note effect where the acid and other liquids meet. This is the most common test for nitric acid and the nitrates.

Reaction. The brown ring test may be represented in an equation thus: $2 \text{KNO}_3 + 4 \text{H}_2\text{SO}_4 + 10 \text{FeSO}_4 = \text{K}_2\text{SO}_4$ (potassium sulfate) + $3 \text{Fe}_2(\text{SO}_4)_3$ (ferric sulfate) + $4 \text{H}_2\text{O} + 2 (\text{FeSO}_4)_2\text{NO}$.

The last compound has no specific name and its composition is involved in uncertainty. (Prescott & Johnson).

IX. Put one drop of HNO_3 in a test tube of water and taste the mixture from a glass rod. Test the same with blue litmus paper.

place half a
 (NH_4NO_3) and
 and collect three
 and the other by
 things *must* be
 as dangerous
 gentle evolution of
 test tube turned
 may not strike

test one of the
 collected by down-

in the remaining
 in oxygen?

place a few pieces



very disagreeable,
 avoid letting much

The reddish fumes formed when NO comes in contact with the air are fumes of nitrogen dioxid (NO_2).

PHOSPHORUS.

SYMBOL P.

ATOMIC WEIGHT 31.

The name phosphorus comes from the Greek, meaning light bearer and has reference to the property of phosphorescence.

Before beginning this experiment read carefully the caution given on page 29. A phosphorus burn makes a disagreeable sore, very difficult to heal.

I. Rub a *small* piece of phosphorus between two pieces of board. The heat of friction will ignite the phosphorus.

II. Place a piece of phosphorus about as large as an apple seed in a six-inch test tube and fill one-half full of water. Drop in three or four large crystals of potassium chlorate (KClO_3). Insert a thistle tube, placing the lower end near or on the phosphorus, then pour two or three cc. of H_2SO_4 through the tube. Note the effect.

III. Touch a piece of phosphorus with a test tube filled with hot water.

IV. Dip a piece of paper in a solution of phosphorus in carbon disulfid (CS_2). Lay it on an iron ring or pan and watch it closely till chemical change occurs.

V. Heat a small quantity of lamp-black in an iron spoon and allow to cool. On a piece of paper or board lay a clean dry piece of phosphorus. Shake a quantity of lamp-black upon it and note the effect. Why does phosphorus smoke when taken out of water?





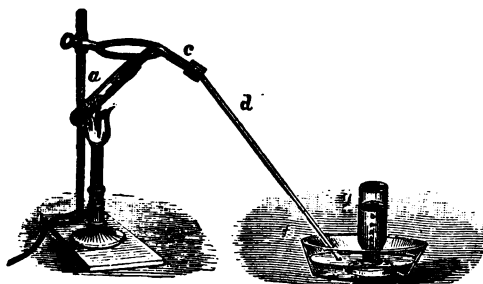
VI. Place a crystal of iodine on a dry piece of phosphorus, phosphorus iodide is formed (PI_3).

CARBON.

SYMBOL C.

ATOMIC WEIGHT 12.

I. Arrange a six-inch test tube, an old one if you have it, with a delivery tube. Fill the tube with shavings or small pieces of wood, and heat. Collect the gas evolved over water and test with a lighted splint. When the gas



ceases to come off, close the tube with a cork, or plaster of Paris, and allow to cool. When cool examine the contents of the tube. What have you? Compare with charcoal. Heat a small piece of the charred wood in an iron spoon. Does it burn with flame? What causes the flame of burning wood?

II. Press down upon the luminous flame of a Bunsen burner a cold iron spoon. Note deposit on the bottom. Why is unburned carbon deposited on the spoon?

III. Make a mixture of one part powdered charcoal or lamp-black to eight of copper oxide (CuO) and heat strongly in a test tube. After heating some time, break the test tube and note the change that has occurred. The CuO has been reduced to metallic copper. Why?

100 cc. capacity
Into the first
iodin and starch.



tions except one.
Which is it? Why
charcoal remove

It may be poured
er and over again.

ator in the same
bottle several small
e with water, and
ntities of concen-
over water or by
method is usually
In a bottle of the
cohol and ignited.
tion? Could you

a little lime water
Continue until

the lower edge of a
card so as to run

properties of CO_2 does
the candle flame just
the lime water until a



the glowing piece of char-
coal ceases to glow
by means of lime

water, i. e., pour in about two cc. of lime water and shake.

VII. Test the air of the room by filling a large bottle with it and shaking up with lime water. To get the air from the room carefully suck out air already in the bottle with a glass tube or fill by using an aspirator. In sucking out the air do not breathe in the bottle. Also test the air of the room by allowing a watch glass full of lime water to stand in the room for an hour or more. Note the surface of lime water. What has formed on it?

Reactions. $\text{CaCO}_3 + 2 \text{HCl} = \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2$.

$\text{CO}_2 + \text{Ca}(\text{HO})_2$ (calcium hydroxid or lime water) = $\text{CaCO}_3 + \text{H}_2\text{O}$.

$\text{CaCO}_3 + \text{CO}_2 + \text{H}_2\text{O} = \text{CaH}_2(\text{CO}_3)_2$ (calcium acid carbonate).

ETHYLENE OR ETHENE.

Carbon forms a vast number of compounds with hydrogen, but only a few of them can be experimented upon in an elementary course.

I. PREPARATION.—In a test tube arranged as for the preparation of nitrous oxid place a mixture of two cc. of alcohol ($\text{C}_2\text{H}_5\text{O}$) and eight cc. of strong sulfuric acid.

Extreme care must be used in mixing acid and alcohol because much heat is developed.

Pour the acid slowly into the alcohol and stir vigorously in the meantime.

Heat the mixture gently and collect the gas, C_2H_4 , over water.

The mass in the test-tube becomes black and froths, therefore it must be watched carefully to prevent frothing over.

II. Test the C_2H_4 in the bottle to see whether it burns or supports combustion.

or as it burns.
gas as in the case

Write the equa-
tion in a bottle of



or water and takes
the gaseous com-
pound so that the ethy-
lene, C_2H_4 , as well as ether

glucose.
($C_6H_{12}O_6$) add a lit-
tle and a few drops of
potassium, drop by drop.
color, if any. It
must not be heated too
highly as sugar may thus be

changed into glucose and the experiment spoiled. Use a four-inch test tube for this experiment.

II. Perform the same experiment with a glucose ($C_6H_{12}O_6$) solution. Note that the color is orange, or reddish brown.

III. Test an unknown solution in the same way.

IV. Test mixed candies and samples of sugar obtained from different stores.

V. To make sugar from starch.

1. Put two cc. of H_2SO_4 into 100 cc. of H_2O in a large evaporating dish of about three-hundred cc. capacity. Allow the mixture to cool.

2. Prepare twenty-five cc. of starch paste by adding starch ($C_6H_{10}O_5$) to twenty-five cc. of water until a thin paste is formed. Warm gently for about two minutes and add water if necessary to make the paste thin enough to flow readily.

3. Bring the solution of acid to boiling and add the starch solution drop by drop stirring continually till all is added. Boil slowly twenty or thirty minutes and then set aside to cool.

During the boiling add water if necessary.

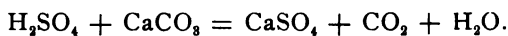
4. Now add pulverized chalk or marble until effervescence ceases, to neutralize the H_2SO_4 . Dip the end of a glass rod into the mixture and touch to the tongue to ascertain if the sour taste of the acid has disappeared.

5. The liquid has probably been changed to a pasty mass by the addition of chalk. Now thin with water and filter.

6. Evaporate the filtrate to dryness and you have a pasty mass of sugar.

Is it glucose or cane sugar?

Reactions. The CuSO_4 is reduced to Cu_2O , a reddish brown cuprous oxid. The acid is neutralized according to the reaction:



The calcium sulfate is insoluble in water and is separated from the sugar solution by filtration.

VI. To make sugar out of sawdust or rags.

To two parts by weight of wood or clean linen rags add three parts of conc. H_2SO_4 . The wood must be in the form of thin shavings or sawdust and the rags cut or torn into shreds. Add the wood or rags gradually to the acid and set aside for twenty-four hours. Dilute with twenty or thirty volumes of water and boil two or three hours, adding water as needed. Neutralize the acid with chalk, dilute with water, filter off the calcium sulfate, evaporate nearly to dryness and test.

What kind of sugar have you this time?

BORON.

SYMBOL B.

ATOMIC WEIGHT 10.86.

I. Preparation of boric or boracic acid (H_3BO_3).

Dissolve half a test tubefull of borax in ten cc. of boiling water in a beaker or small evaporating dish and add to the solution 2.5 cc. of concentrated hydrochloric acid. As soon as the solution cools crystals of boric acid will be deposited on the bottom of the dish.

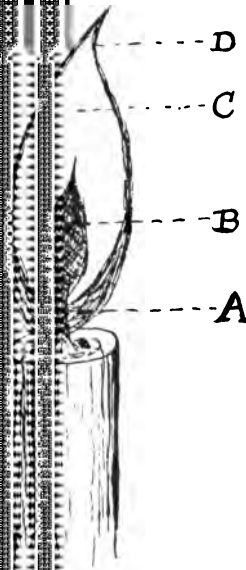
II. Test for boric acid.

Dissolve a little of the boric acid you have made in alcohol in an iron spoon. Ignite the alcohol and stir the burning solution with a glass rod. The flame will be colored green.

III. To make boric anhydrid (B_2O_3). In a clean iron spoon, heat some crystals of boric acid. As soon as

hydride will be left
in long threads
on a stick or glass
rod of glass.

is divided into four parts. A.
the flame at the base
is merely a thick



portion in it. You
in this portion of
the experiment is
In the next portion
the supply of air is



not sufficient to burn up all the gases formed. These are all compounds of hydrogen and carbon and in this zone they are partially consumed, burning to CO_2 and water, but a large part of the carbon is merely heated white hot thus rendering the flame luminous. Outside of the luminous zone is an almost invisible coat where the gases are completely consumed. The ultimate products of all the gases burned are carbon dioxide and water.

II. Press down upon a candle flame a piece of white letter paper or some other heavy paper until it almost touches the wick. Observe the charred ring with a white center. Cause? Which is the hottest part of the flame?

III. Hold a thin wire, either iron or platinum, across a candle flame or luminous burner flame. Note where the wire is hottest. Repeat with a piece of wire gauze. Repeat with a match stub or piece of wood.

B. NATURE OF FLAME.

I. Blow out the candle, then ignite the smoke. Why does it ignite?

II. Place a piece of wire gauze on a ring stand and turn on the gas in a burner placed under it. Now above the gauze light the gas. It will burn for some time above the gauze. Turn off the gas and allow the gauze to cool. Again light the gas, this time under the gauze. Why does the flame not pass through the gauze?

III. Heat a small glass tube until quite warm and at once place the end in the dark center of the candle flame and ignite the gas at the other end of the tube. What does this show?

C. LUMINOSITY OF FLAME.

I. Stop the holes of the Bunsen burner and note the effect. Why is this? Compare color of flames when the

holes are open and when they are shut. Take a burner apart and notice its construction. What is the use of allowing the air to enter the lower part of the tube and thus mix with the illuminating gas in it?

Rub two pieces of charcoal together over the blue flame and note the effect.

II. Press a cold spoon down on both burner flames and note effect. What makes the flame luminous? Which is the hotter of the two flames? Why?

D. CHEMISTRY OF FLAME.

I. Hold a candle in a wide mouthed bottle till it goes out.

II. Test the contents of the bottle by shaking up with lime water. One cc. is enough.

III. Hold a cold clean bottle over a luminous flame and note the deposit.

E. BLOWPIPE FLAME.

Close the holes in the Bunsen burner by turning the tube. Obtain the oxidizing flame by placing the blowpipe tip inside the dark portion of the flame just over the top of the burner, and blow across the flame somewhat strongly. An almost colorless pointed flame is produced. The reducing flame is obtained by placing the tip a little higher above the burner top and outside the flame. A luminous flame is produced. Which is the hotter? Why? When making these two flames do not blow so hard as to make much noise.

In the above Richter's 8th edition has been substantially followed.

METALS.

PRINCIPLES.

In the following statements the term salt includes only cases where the metal acts as a base, e. g., chromium salts include CrCl_3 , not K_2CrO_4 .

1. **Hydroxids** when brought in contact with acids form salts, provided they can be formed by any means in the presence of water. The same is true of oxids, except that ignited chromic oxid does not dissolve in acids.

2. All **nitrates**, **chlorates**, and **acetates** are soluble, but all salts of bismuth, tin, antimony, and the oxysalts of mercury, require some free acids to hold them in solution.

3. All **oxids** and **hydroxids** are insoluble, except those of the alkalis, those of the fourth group slightly soluble. The fixed alkalis precipitate solutions of all other metallic salts, the fourth group incompletely. The precipitate with silver, antimony and mercury is an oxid, in all other cases a hydroxid. This precipitate redissolves in eight cases, forming, if potassium hydroxid be used . . . K_2PbO_2 , K_2SnO_2 , K_2SnO_3 , KSbO_2 , KSbO_3 , K_2ZnO_2 , KAlO_2 , KCrO_2 . The latter reprecipitates on boiling.

4. **Ammonium hydroxid** precipitates solutions of the first three groups, manganese and magnesium imperfectly and not at all if ammonium chlorid be present. The precipitate is a hydroxid, except that with silver and antimony it is an oxid, with lead a basic salt, and with mercury

a peculiar salt. The precipitate redissolves in six cases, viz., silver, copper, cadmium, cobalt, nickel, and zinc. With silver NH_4AgO is formed, with zinc $(\text{NH}_4)_2\text{ZnO}_2$.

5. The **chlorids** of the first group are insoluble, lead chlorid slightly soluble. **Hydrochloric acid** and **soluble chlorids** precipitate solutions of the salts of the first group, lead salts incompletely. (For higher oxids, see Prescott & Johnson, p. 251).

6. The **bromids** of lead, silver, and mercury are insoluble, mercuric bromid slightly soluble. **Hydrobromic acid** and **soluble bromids** precipitate solutions of lead, silver, and mercury, mercuric salts incompletely. (For higher oxids, see page 262, P. and J.)

The **iodids** of lead, silver, mercury, and cuprosium are insoluble. **Hydriodic acid** and **soluble iodids** precipitate solutions of lead, silver, mercury, and cuprosium. Cupric salts are precipitated as cuprous iodid with liberation of iodine. Ferric salts are merely reduced to ferrous salts with liberation of iodine.

8. The **sulfates** of lead, mercurous, barium, strontium, and calcium are insoluble, those of calcium and mercurous slightly soluble.

Sulfuric acid and **soluble sulfates** precipitate solutions of lead, mercurous, barium, strontium, and calcium; calcium and mercurous incompletely.

9a. The **sulfids** of the first three groups are insoluble. **Hydrosulphuric acid** transposes salts of the first two groups in acid, neutral, and alkaline mixtures.

Ferric solutions are reduced to ferrous with liberation of sulfur.

9b. **Soluble sulfids** transpose salts of the first three groups. The result is a sulfid, except that with aluminum and chromium salts it is a hydroxid, hydrogen sulfid being

evolved. With mercurous salts, mercuric sulfid and mercury are formed; with ferric salts, ferrous sulfid, and sulfur.

10. The **carbonates** of the **alkalis** are soluble.
(Condensed from Prescott & Johnson.)

DEFINITIONS.

A *precipitate* is a substance insoluble in the liquid which is present with it.

Filtration is the process of separating the precipitate from the liquid in which it is held, by pouring the whole on a filter paper in a funnel. The liquid runs through but the precipitate remains on the paper. The liquid is called the *filtrate*.

Decantation is the process of pouring off the liquid which holds a precipitate after allowing the precipitate to settle to the bottom of the vessel.

Reagent is the name applied to any known substance which is used in making an analysis.

Analysis is divided into two classes, Qualitative and Quantitative. A *qualitative* analysis is the name applied to the process of finding out what an unknown substance contains. *Quantitative* analysis proceeds further and determines the quantity of each ingredient.

GROUPING OF THE METALS.

The metals are grouped for purposes of analysis into five groups according as they are precipitated by certain reagents. The reagent which precipitates a whole group is called a group reagent.

- I. Metals precipitated by hydrochloric acid; Lead, Mercury (monad), Silver.

Of these metals the chlorids are insoluble in water except lead chlorid which is slightly soluble.

II. Metals precipitated by hydrogen sulfid.

These precipitates are insoluble in cold dilute acids but readily soluble in warm.

Mercury (diad), Lead, Bismuth, Cadimium, Arsenic, Tin and Antimony belong to this group.

III. Metals not precipitated by the two first group reagents, but precipitated by ammonium hydroxide (NH_4OH) and hydrogen sulfid in the presence of ammonium chlorid. The ammonium chlorid is used to prevent the precipitation of magnesium, a fifth group metal. Iron, Chromium, Aluminum, Cobalt, Nickel, Manganese and Zinc belong to this group.

IV. Metals not precipitated by the reagents of groups one, two and three, but by ammonium carbonate ($\text{NH}_4)_2\text{CO}_3$ in presence of NH_4OH and NH_4Cl . Barium, Calcium and Strontium belong here.

V. Group V contains all metals not in the other groups. They are not precipitated by any of the above mentioned reagents. Fifth group metals are Magnesium, Potassium, Sodium and Ammonium (NH_4 .)

LEAD.

SYMBOL Pb.

ATOMIC WEIGHT 205.4.

GALENA.

- A. 1. Examine the specimen as to,
 - a. Form.
 - b. Hardness.
 - c. Malleability.
 - d. Marking on paper.
2. Heat specimen on charcoal alone with the blow pipe.

- Note:
- Color of coat (the deposit on the charcoal) hot and cold.
 - Distance of coat from assay piece.
 - Effect of *Reducing* flame on the coat. (Azure blue.)
 - Effect of oxidizing flame on coat.

Use a very small piece of galena, a piece not larger than a pin head.

- Obtain the bead. (The little globule of metal.)

Is it malleable? Easily cut? Will it mark paper?

Will the finger nail scratch it?

- Heat a small piece of galena on charcoal with sodium carbonate Na_2CO_3 , note the coats as above. Do you get a malleable bead as before? What is this bead? Where has the sulfur gone to? Write the equation.

- To make a solution. Try

- Water cold and hot.
- Hydrochloric acid cold and hot.
- Nitric acid cold and hot.

Reaction. $3 \text{Pb} + 8 \text{HNO}_3 = 3 \text{Pb}(\text{NO}_3)_2$ (lead nitrate) $+ 2 \text{NO} + 4 \text{H}_2\text{O}$.

NOTE.—After dissolving a metal in acid it is necessary to evaporate the solution nearly to dryness before testing. This removes any excess of acid. The solution may be diluted with water after evaporation to make a quantity great enough to work with.

B. Repeat the foregoing experiments with commercial lead.

C. Mix the solution from galena with that made from lead and test as follows.

To a small quantity of the solution in a test tube add a few drops of hydrochloric acid, note the precipitate and write the reaction. Repeat with H_2S , with H_2SO_4 ,

$K_2Cr_2O_7$, (potassium dichromate) and KI (potassium iodid).
Tabulate your results and write out the reactions as follows.

Solution. $Pb(NO_3)_2 + HCl = \underset{\text{WHITE}}{PbCl_2}$ (lead chlorid) + ?

“ $+ H_2S = PbS + ?$

“ $+ H_2SO_4 = PbSO_4$ (lead sulfate)
+ ?

“ $+ K_2Cr_2O_7 = PbCrO_4 + CrO_3$
+ 2 KNO_3 .

“ $+ KI = PbI_2 + ?$

SILVER.

SYMBOL Ag.

ATOMIC WEIGHT 107.11.

I. Heat a specimen of silver ore on charcoal alone in the reducing flame.

- a. Obtain a bright bead.
- b. Note color of the coat.
- c. Heat a very long time in the reducing flame. Note a slight dark red coat.

II. Heat on charcoal with sodium carbonate in the reducing flame.

- a. Obtain the bead.
- b. Note time required for reduction as compared with I. What purpose does the carbonate serve ?

III. Solution. Try

- a. Water cold and hot.
- b. Dilute nitric acid cold and hot.
- c. Concentrated nitric acid cold and hot.

Evaporate the solution to expel an excess of acid and test after diluting with water as follows.

Solution + $HCl = AgCl$ (silver chlorid) + ?

The white precipitate of the above + warm NH_4OH goes into solution once more with formation of $(\text{NH}_4)_2(\text{AgCl})_2$ (ammonio silver chlorid).

Solution + FeSO_4 = a black or dark precipitate of silver.

Sol. + H_2S = Ag_2S + ?

Sol. + KI = AgI + ?

Finish up as many of the equations as you can and write the equation for solution of silver in nitric acid. If you have difficulty in doing this last perform the experiment once more and notice what gas is given off.

MERCURY.

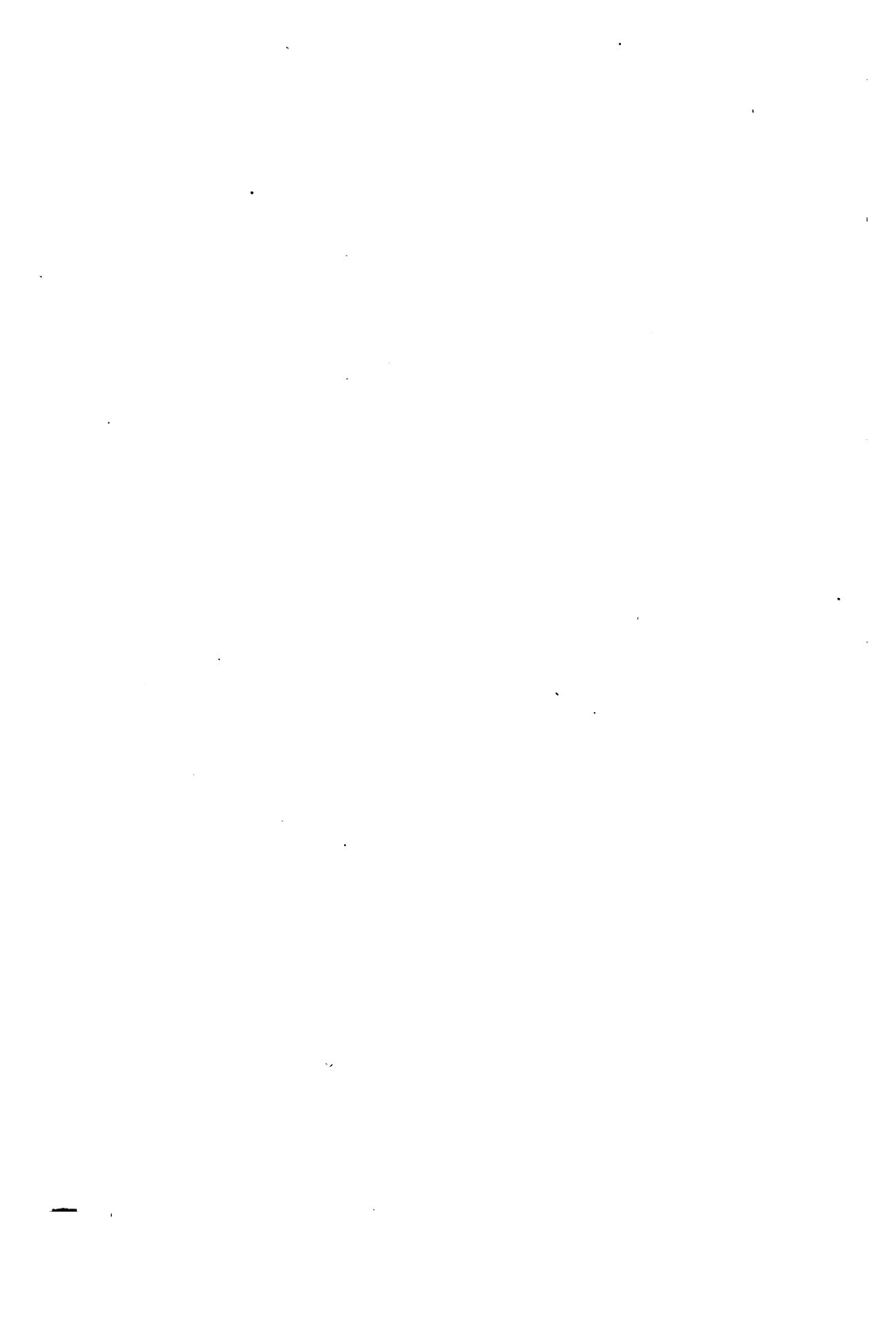
SYMBOL Hg.

ATOMIC WEIGHT 198.49.

The symbol comes from the Latin name of mercury, hydrargyrum. It occurs chiefly in the form of its sulfid (HgS) called cinnabar. Mercury occurs in two forms, as a monad, that is combining with or replacing one atom of hydrogen; also as a diad, combining with or replacing two atoms. It forms two different classes of salts. The chlorid of the monad is insoluble in water while the diad (HgCl_2) is easily soluble. The first is non-poisonous and is much used in medicine under the name of calomel. The other is the very poisonous corrosive sublimate.

A. Cinnabar (HgS).

1. Note the color of a large piece.
2. Powder, then note color again.
3. Heat on charcoal alone. It volatilizes.
4. Heat on charcoal with sodium carbonate in the reducing flame.
5. Heat in a glass tube with carbonate and note mirror like deposit on the cold walls of the tube.

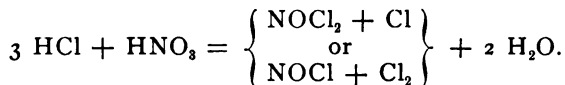


B. Solution.

1. Put three parts of hydrochloric acid in one test tube and two parts nitric in another. Now put a little powdered cinnabar in each and note the effect.

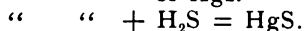
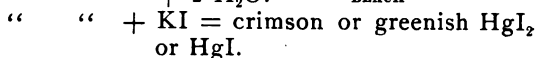
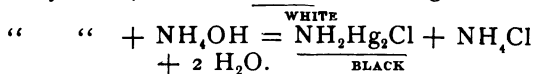
2. Pour the contents of the two tubes together and note effect. Evaporate under the hood, dilute with water and test as under 3.

Reaction. When nitric and hydrochloric acids are brought together chlorine and an oxychloride of nitrogen are set free. The chlorine when first made or nascent is a very active agent and dissolves mercury quickly, forming mercuric chloride. Mercurous nitrate is formed sometimes when the solution is not heated.



At the same time that the mercury is dissolved the sulfur of the cinnabar is changed into sulfuric acid. Test your solution for sulfuric acid with barium chloride.

3. Mercury sol. + HCl = HgCl or nothing.



After testing the solution you have made try a solution of some monad mercury compound and of some diad. Which have you made?

SEPARATIONS IN GROUP I.

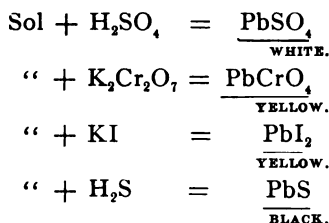
Mix a solution of mercury with one of lead and silver. (This may be done by the instructor) Now to a quantity of the solution add HCl slowly, shake and allow to settle. Add more till no more precipitate is formed. Filter.

Pb Cl₂. Ag Cl. Hg Cl.

I. *Precipitate*.—Place on a filter and wash with a little distilled water. Now pour about twenty-five cc. boiling water on the precipitate and collect the solution in another test tube. Save the undissolved precipitate and test the filtrate by table 1. The hot water dissolves the lead chlorid so the hot solution contains lead if any is present.

Table 1.

LEAD Pb.



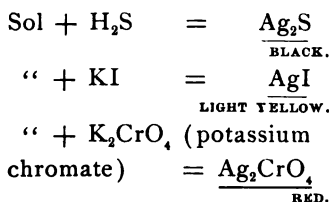
See article on lead.

Write out all the equations.

II. Pour warm ammonia on the undissolved precipitate and the silver chlorid will be dissolved, forming ammonio silver chlorid (NH₃)₂(AgCl)₂. See article on silver. Filter and test the filtrate by table 2.

Table 2.

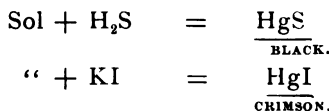
SILVER AG.



III. If a black residue remains from II. mercury is indicated. Dissolve in nitrohydrochloric acid, dilute with water and test by table 3. If no residue is left of course this last is unnecessary.

Table 3.

MERCURY Hg.



Use as small quantities of reagents as possible in all these tests.

GROUP.

s. I. Includes
Now ammonium



As_2O_3 in hot water.

$+$?

$\text{AsO}_3 + ?$

(green). When

the well known

$(\text{H}_2\text{O}_2)_2$.

under hood). As

for a novice it is

element. Make a

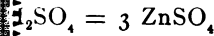
hydrogen from a

Wolf's bottle as

is a safety tube.
 is apparatus, as
 books, but that



left on the por-
 to the generator a
 an absolutely free
 formed according
 in the air
 deposited on the



performed except
 are *extremely*

on porcelain.
 It dissolves.
 drop of bleaching
 the test is applied
 is insoluble in a

1701

ANTIMONY.

SYMBOL Sb.

ATOMIC WEIGHT 119.52.

The symbol Sb comes from the Latin name of antimony, stibium.

I. Make a solution of antimony by dissolving the metallic antimony in nitrohydrochloric acid. Try also hydrochloric acid. Do not evaporate this time.

II. To a small portion of the hydrochloric acid solution add some water. A white powder is precipitated. This is characteristic of antimony and bismuth. A white basic chlorid is formed.

Solution + $H_2S = Sb_2S_3$ (antimonius sulfid). This is of a bright orange color and this test is more often used for antimony than any other.

III. Try the Marsh's test for antimony. Obtain the spots. Compare with arsenic spots. Test with a bleaching powder solution. The spots do not dissolve. Try to dissolve a spot in hot nitric acid. How can you tell the difference between spots of arsenic and antimony?

The antimony solution with hydrochloric acid and zinc forms a gaseous compound called stibin (SbH_3), which is much like arsin though not so poisonous.

TIN.

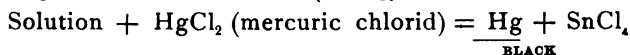
SYMBOL Sn.

ATOMIC WEIGHT 118.15.

The symbol comes from the Latin name stannum.

I. Examine a piece of metallic tin. Bend the piece noting the crackling sound. This sound is very characteristic of tin. It is supposed that a piece of tin is composed of a great number of minute crystals or granules, which rub upon one another when the piece is bent.

II. Solution. Try HCl cold and hot. Test the gas generated with a flame. What is it? Write the equation knowing that stannous chlorid (SnCl_2) is formed.



SnCl_4 is stannic chlorid. This test is used to determine both mercury and tin. Note that before the black mercury is precipitated a white powder is formed. This is HgCl_2 . Compare with the analysis of first group metals.

Solution + $\text{H}_2\text{S} = \text{SnS}$ (Stannous sulfid.) Treat a bit

BROWN

of this sulfid with HCl. What is formed? Write the equation.

$\text{Sol} + \text{NH}_4\text{OH} + \text{a zinc strip} = \text{a deposit of metallic tin on the zinc.}$ The ammonia is used to make the solution alkaline.

The metals of this first class may be easily distinguished from each other by the color of the precipitates which they form with hydrogen sulfid.

METALS OF THE SECOND GROUP.

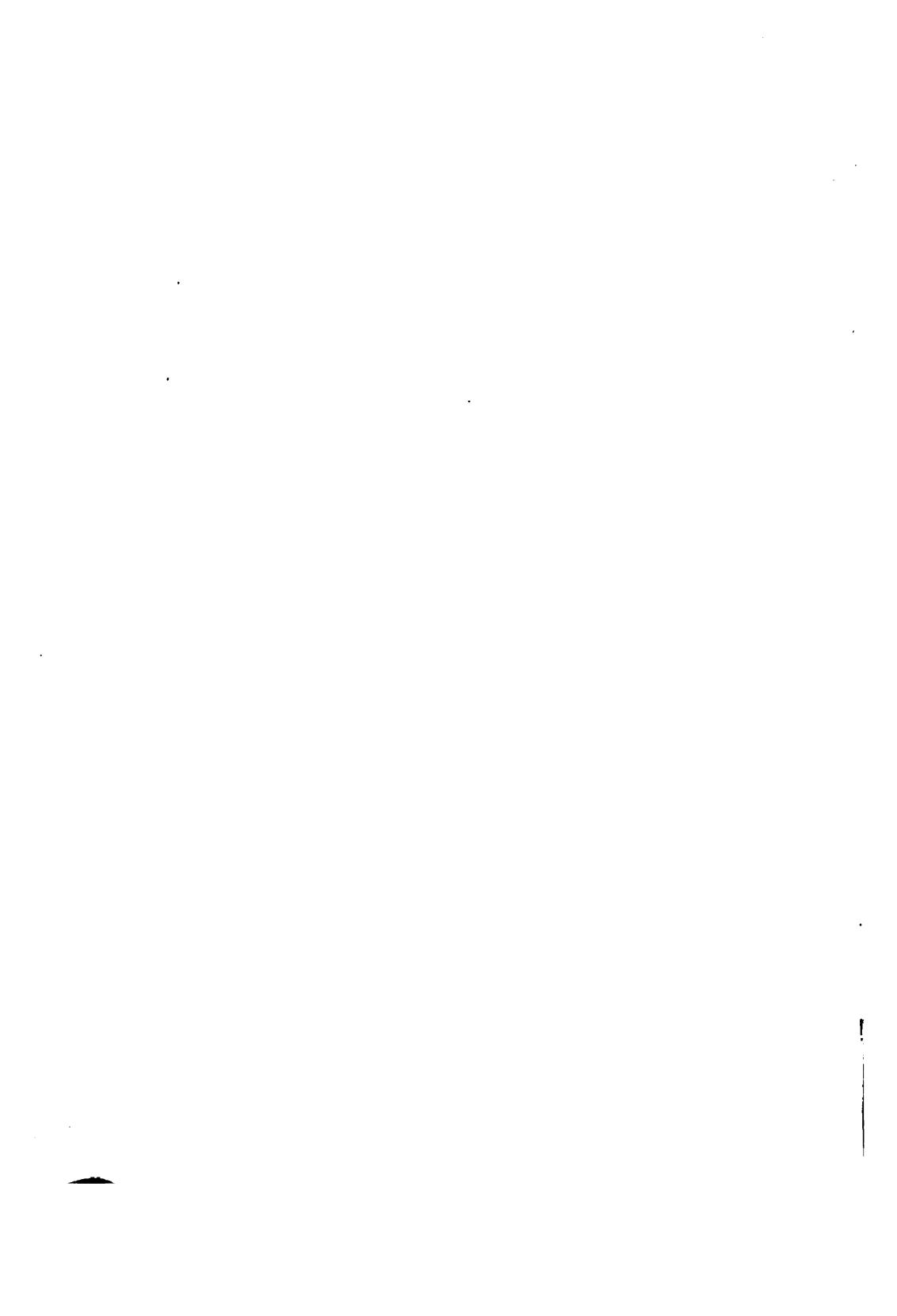
CLASS 2.

The sulfids of this class are insoluble in yellow ammonium sulfid. It contains lead, copper, cadmium, bismuth and the diad mercury. Lead occurs in this group as well as in the first because it is but imperfectly removed by HCl.

MERCURY (DIAD).

See discussion of mercury under group I.

NOTE. When a diad mercury salt is precipitated by H_2S , first a greenish precipitate is formed which gradually changes to black.



COPPER.

SYMBOL Cu.

ATOMIC WEIGHT 63.12.

Symbol comes from the Latin name cuprum.

COPPER OXID CuO.

I. Examinespecimen. Note color, form, weight, etc.

II. Heat on charcoal in the reducing flame alone.

III. Heat on charcoal in the reducing flame with sodium carbonate. Examine the bead thus formed. Color, etc. You have metallic copper.

IV. Heat a mixture of equal parts of powdered charcoal or lamp black and copper oxid in a small glass tube. What is formed? What becomes of the oxygen of the copper oxid? Answer experimentally. Compare copper thus formed with a metallic specimen.

V. Solution. Try HCl cold and hot, HNO₃ cold and hot. What gas is formed in the latter case? Write the equation. Note the color of the solution. Note the color of all the copper solutions in the laboratory that you can find. CuSO₄, Cu(NO₃)₂, Cu(C₂H₃O₂)₂, CuCl₂, etc. What seems to be the characteristic color.

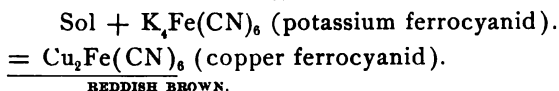
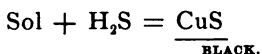
Try concentrated sulfuric acid cold then hot. *Be very careful* in handling hot concentrated sulfuric acid as it is a very dangerous body. Note the odor of the gas thus formed. Where has this same reaction been used before? Write the equation.

VI. Use the nitric acid solution for the following tests after having first freed it from excess of acid.

You have a solution of Cu(NO₃)₂ (copper nitrate.)

Sol + an iron wire = metallic Cu.

Sol + NH₄OH = (N₂H₈Cu)O(NH₄NO₃)₂ a deep blue solution called cuprammonium nitrate.



Finish all these equations.

VII. Dip a platinum wire in any copper solution, then hold it in the colorless flame of a Bunsen burner. Note color given to flame. Have we studied any other elements which might be confounded with Cu in this test?

VIII. Bend a small loop in a piece of platinum wire and heat it in the colorless flame of a burner to redness. Plunge it while hot into a bottle of powdered borax and heat again until a clear bead is obtained. Dip the bead in a copper solution and heat with the blowpipe, using the oxidizing flame. The bead will be green while hot and blue when cool. Make this test several times so as to become skilful.

CADMIUM.

SYMBOL Cd.

ATOMIC WEIGHT 111.10.

Cadmium is quite rare. If a soluble salt of the metal can be obtained make a solution and precipitate the cadmium with hydrogen sulfid. Note color of precipitate. It is cadmium sulfid (CdS.) Write the equation.

SEPARATIONS IN GROUP II.

CLASS I.

Make a solution containing several first and some second group metals and try to separate them according to the following scheme.

I. After all the first group has been removed by hydrochloric acid, the second group remains. Now to the filtrate from group one add hydrogen sulfid until no more

precipitate is formed. The precipitate may contain As_2S_3 , Sb_2S_3 , SnS , PbS , HgS , CdS , CuS or Bi_2S_3 .

II. Dissolve out sulfids of class 1, by heating the whole precipitate with yellow ammonium sulfid in a test tube.

III. Filter and save precipitate for class 2. Neutralize the ammonia of the ammonium sulfid with hydrochloric acid and the precipitates of arsenic, antimony and tin are thrown down again. You can see whether one metal is present or several by the color of the sulfid. If the color is a clear yellow, arsenic is indicated (page 97); if orange, antimony (page 101); if brown, tin (page 103). But if the color is indistinct there may be a mixture of these metals present and the Marsh's test must be resorted to.

CLASS 2.

Contains the Sulfids of Mercury, Lead, Bismuth, Copper, and Cadmium.

1. Wash the precipitate which remains undissolved in ammonium sulfid and water.
 2. Dissolve the precipitate in hot dilute nitric acid. Expel excess acid and dilute with water.
- NOTE.—The sulfids of lead, bismuth, copper and cadmium dissolve in HNO_3 . HgS does not.

<p>I. RESIDUE HgS. Dissolve the black precipitate in a little nitro-hydrochloric acid. Expel the excess of acid and dilute with water. Test for mercury with:</p> <ol style="list-style-type: none"> 1. Potassium iodid gives a red precipitate Hg_2I_2. 2. Stannous chlorid = a black precipitate of metallic mercury. (See the article on tin). 	<p>II. SOLUTION: <i>May contain</i> $\text{Pb}(\text{NO}_3)_2$, $\text{Bi}(\text{NO}_3)_3$, $\text{Cu}(\text{NO}_3)_2$ or $\text{Cd}(\text{NO}_3)_2$. To a portion of the solution add a drop of dilute sulfuric acid. If there is a precipitate add to the whole solution, warm and filter. This removes the lead.</p> <p>PRECIPITATE: <i>Lead.</i> To confirm for lead, test some of the precipitate by heating on platinum foil or in a crucible with potassium chromate or dichromate. Yellow lead chromate is formed PbCrO_4.</p>	<p>III. FILTRATE from II: <i>May contain</i> $\text{Bi}(\text{NO}_3)_3$, $\text{Cu}(\text{NO}_3)_2$, or $\text{Cd}(\text{NO}_3)_2$. Add ammonia to neutralize acid and precipitate bismuth. Copper and cadmium remain in solution.</p> <p>IV. PRECIPITATE: $\text{Bi}(\text{OH})_3$, $\text{Cu}(\text{OH})_2$ or $\text{Cd}(\text{OH})_2$. Filter and wash precipitate and test by potassium stannite K_2SnO_3 thus. Add potassium hydroxid (KOH) to a solution of stannous chlorid until the precipitate first formed dissolves again. Potassium stannite is formed which when added to the $\text{Bi}(\text{OH})_3$ will turn the precipitate black with formation of dibismuth dioxid Bi_2O_3.</p>	<p>V. SOLUTION: $\text{Cu}(\text{NO}_3)_2$ or $\text{Cd}(\text{NO}_3)_2$. When the bismuth is precipitated if copper is present blue cuprammonium compounds will be formed. (See copper). To confirm, test solution on a platinum wire.</p> <p>VI. CADMIUM. Copper and cadmium may have been present together. From the ammonia solution precipitate both again with hydrogen sulfid. Dissolve the precipitate in hot dilute H_2SO_4. Cadmium sulfid dissolves but copper sulfid does not. Precipitate the solution once more with hydrogen sulfid. A yellow precipitate CdS will be formed if cadmium is present.</p>
--	--	--	---

THIRD GROUP METALS.

The metals of the third group are also divided into two classes, A and B. Class A includes metals which are precipitated by NH_4OH in the presence of NH_4Cl . Such are chromium, iron and aluminum.

To class B belong those metals not precipitated by NH_4OH and NH_4Cl , but by ammonium sulfid $(\text{NH}_4)_2\text{S}$. Cobalt, nickel, manganese and zinc belong to this class.

IRON.

SYMBOL Fe.

ATOMIC WEIGHT 56.

The symbol comes from the Latin name *ferrum*. Iron forms two classes of salts, ferrous or diad and ferric or triad salts. The diad salt is very easily converted into the triad by exposure to the air, so that nearly all diad compounds will give tests for the triad or ferric compounds.

Solution. Iron has several solvents, but its action is somewhat peculiar with each. Note what is formed in each of the following cases.

I. Dissolve some iron wire in HCl . What gas is set free? FeCl_2 is formed which rapidly changes to FeCl_3 .

II. Try H_2SO_4 cold, then hot. In which case is the action most rapid? What gas is formed? Where have we seen this reaction before? Ferric sulfate is formed. Write the complete equation.

III. Try hot dilute nitric acid. Note gas formed. What other metals set free this same gas on solution in HNO_3 ? The ferric salt is produced. Write the equation. You now have solutions of ferrous and ferric salts. Test them according to the following:

DISTINCTION BETWEEN FERROUS AND FERRIC IRON.

1. Ferric compounds.

- a. Potassium ferricyanid gives no precipitate, but a green color.
- b. Potassium sulfocyanid gives a blood red precipitate.
- c. Potassium ferrocyanid gives a blue precipitate.

2. Ferrous compounds.

- a. Ferricyanids give a deep blue precipitate.
- b. Sulfocyanids give no change.
- c. Ferrocyanids give a pale blue precipitate.

Note the difference in the color between ferrous and ferric compounds.

Equations:

1. Ferric compounds.

- a. $\text{FeCl}_3 + \text{K}_3\text{Fe}(\text{CN})_6 = \text{o.}$
- b. $2 \text{FeCl}_3 + 6 \text{KCNS} = \text{Fe}_2(\text{CNS})_6 + ?$
- c. $4 \text{FeCl}_3 + 3 \text{K}_4\text{Fe}(\text{CN})_6 = \text{Fe}_4(\text{Fe}(\text{CN})_6)_3 + 12 \text{KCl.}$

2. Ferrous compounds.

- a. $3 \text{FeSO}_4 + 2 \text{K}_3\text{Fe}(\text{CN})_6 = \text{Fe}_3\text{Fe}_2(\text{CN})_{12} + 3 \text{K}_2\text{SO}_4.$
- b. $\text{FeSO}_4 + \text{KCNS} = \text{o.}$
- c. $\text{FeSO}_4 + \text{K}_4\text{Fe}(\text{CN})_6 = \text{K}_2\text{FeFe}(\text{CN})_6 + \text{K}_2\text{SO}_4.$

CHROMIUM.

SYMBOL CR.

ATOMIC WEIGHT, 52.

The metal chromium is quite rare. It is most familiar to us in the form of some of its salts, as chrome alum ($\text{K}_2\text{Cr}_2(\text{SO}_4)_4 + 24 \text{H}_2\text{O}$), Potassium chromate (K_2CrO_4), potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$), etc.

I. Make a solution of $K_2Cr_2O_7$ in water by dissolving one part of the salt in about ten or fifteen parts of water.

II. Add to a small portion a few drops of $AgNO_3$ solution. A red precipitate of Ag_2CrO_4 is formed.

III. Add H_2S to a little of the $K_2Cr_2O_7$ solution. The color changes from yellow or orange to green. Very characteristic of chromium. Add lead acetate $Pb(C_2H_3O_2)_2$, you obtain as a yellow precipitate lead chromate $PbCrO_4$.

ALUMINUM.

SYMBOL AL.

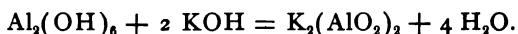
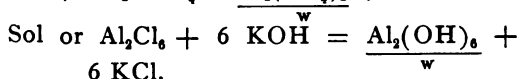
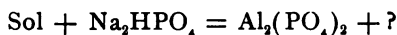
ATOMIC WEIGHT, 27.

Aluminum is best known to us in the compound, $KAl(SO_4)_2 + 12 H_2O$, common alum, and, in the metallic form.

It is a white metal of very low specific gravity.

I. Make a solution by dissolving the metal in HCl or a piece of alum in water.

II. Tests:



Complete the equations according to solution used.

When a salt of aluminum is precipitated with a hydroxid $Al_2(OH)_6$, a white precipitate, is first formed. On addition of more hydroxid this dissolves to form $K_2(AlO_2)_2$ provided KOH was used. An addition of ammonium chlorid prevents the precipitate from redissolving. Compare potassium aluminate ($K_2(AlO_2)_2$) with potassium stannite (K_2SnO_2).

NICKEL AND COBALT.

These two metals are alike in many respects, and as they are nearly always found associated they may be considered together. Considerable difficulty is always experienced in separating them, hence it will be better for the beginner not to attempt it.

NICKEL.

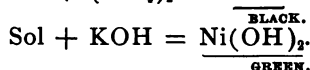
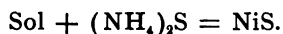
SYMBOL Ni.

ATOMIC WEIGHT, 58.24.

I. Test a nickel salt on a borax bead with the oxidizing flame, you should obtain a bead which is brownish red while hot and yellow when cold.

II. Try the same with a cobalt salt. The bead will be blue.

III. Test a nickel solution with NH_4OH , at first a green precipitate of $\text{Ni}(\text{OH})_2$ is formed. An excess of NH_4OH gives a blue solution.



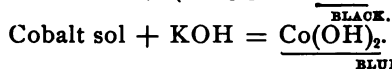
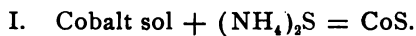
Complete the equations.

IV. Dissolve a five cent piece in nitric acid and find out what it contains.

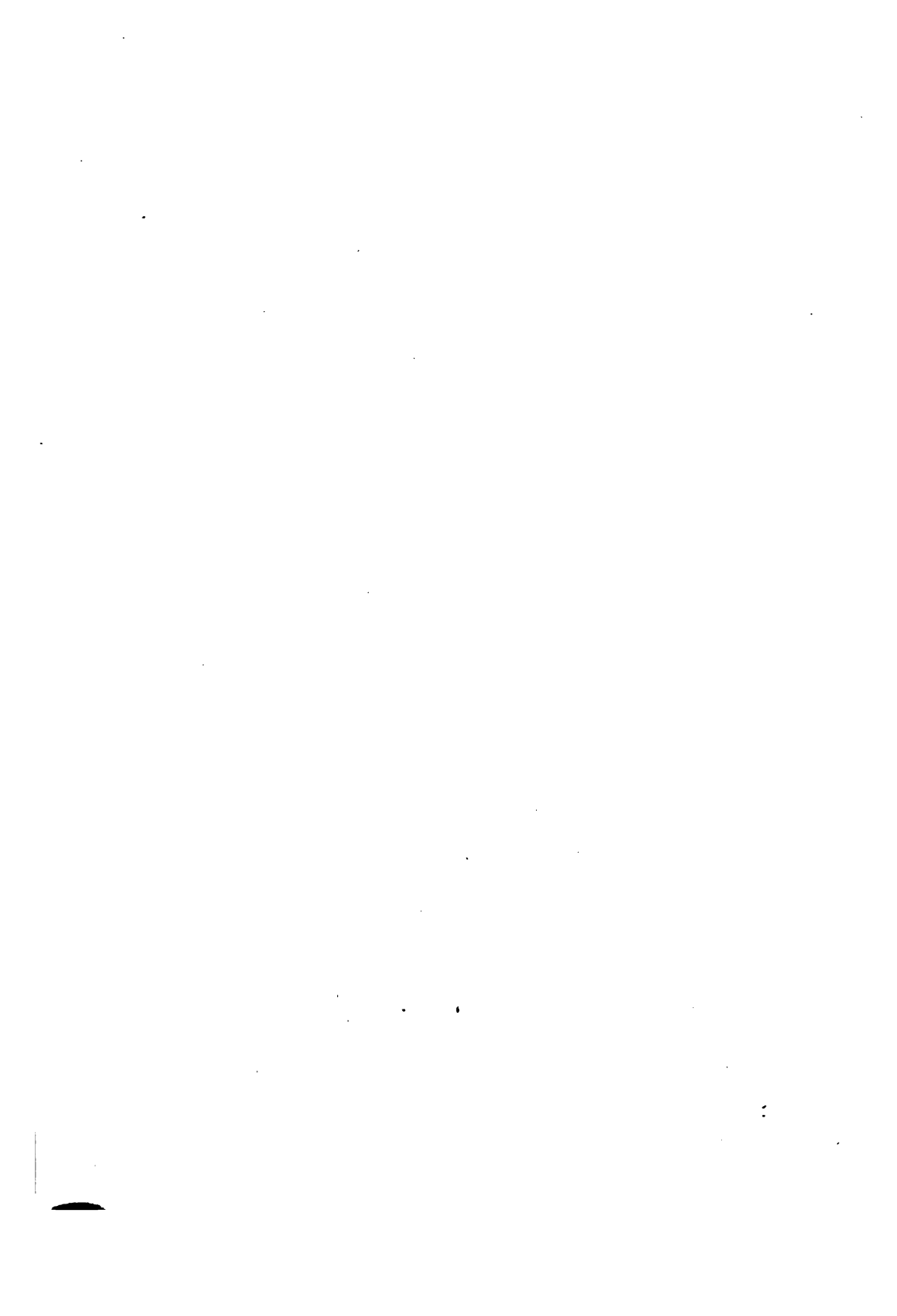
COBALT.

SYMBOL Co.

ATOMIC WEIGHT, 58.49.



Cobalt sol + Na_2CO_3 = a red basic carbonate of cobalt, which when boiled produces a violet or blue solution.



MANGANESE.

SYMBOL Mn.

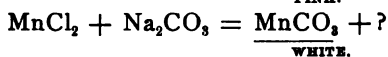
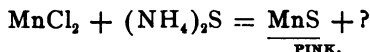
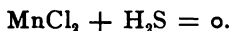
ATOMIC WEIGHT, 54.57.

The chief sources of manganese are the ores Rhodochrosite (MnCO_3), Manganite ($\text{Mn}_2\text{O}_3(\text{OH})_2$), Pyrolusite (MnO_2), etc.

I. Dissolve a very small quantity of manganese dioxide (MnO_2) in hydrochloric acid. What gas is set free? Write the equation for the reaction. You now have a solution of manganese chlorid (MnCl_2). Expel excess of acid and dilute.

II. Into a quantity of MnCl_2 in a test tube run hydrogen sulfid. What happens? To the solution containing H_2S add ammonia. Note change. To a manganese solution add sodium carbonate.

Reactions:



III. Boil a small quantity of manganese chlorid solution with nitric acid and lead dioxid (PbO_2) or red lead (Pb_3O_4). When the sediment subsides a purple solution will be seen. This is permanganic acid ($\text{H}_2\text{Mn}_2\text{O}_8$).

IV. Heat a small quantity of MnO_2 in a borax bead in the oxidizing flame of the blow pipe. A violet bead will be obtained which will slowly change to red when cool. Heat the red bead in the reducing flame and the color will disappear. This red color is caused by manganic oxid, which is the coloring matter of several minerals, such as amethyst, etc.

ZINC.

SYMBOL ZN.

ATOMIC WEIGHT 64.91.

Zinc never occurs free in nature. It is found usually as a silicate in the mineral Willemite (ZnSiO_3), as a sulfid in zinc blende (ZnS), as a carbonate in Smithsonite (ZnCO_3), etc.

I. Dissolve a piece of zinc in hydrochloric acid. What gas is formed? What salt of zinc have you? Try the same with sulfuric acid. What is formed this time?

II. To a solution of some zinc salt add H_2S . No precipitate should be formed. To the solution containing H_2S add ammonia. A white precipitate of zinc sulfid (ZnS) is formed. Write the reaction. (Hydrogen sulfid has no action on metals of the third group, but when an alkali such as ammonia is present an alkaline sulfid is formed which precipitates the metals).

NOTE.—Either of the solutions made in I. when freed from excess acid may be used in this experiment.

III. To a zinc solution add a solution of sodium carbonate, zinc carbonate (ZnCO_3) is formed. Write out all the equations for the above.

IV. On a piece of charcoal heat a very small piece of zinc with sodium carbonate in the oxidizing flame. A yellow coating of zinc oxid is formed which changes to white on cooling. Moisten this coating with a solution of cobaltous nitrate. The coat is changed to green.

SEPARATIONS IN GROUP III.

May Contain Iron, Chromium, Aluminum, Nickel, Cobalt, Manganese and Zinc.

To the clear filtrate left from Group II, which has been freed from hydrogen sulfid by boiling, add a few

drops of nitric acid and boil to change ferrous iron to ferric if iron should be present. Add ammonium chlorid and ammonia until the solution smells strongly. If a precipitate is formed filter and wash.

PRECIPITATE: *Class A of Third Group. May contain ferric hydroxid ($Fe(OH)_3$), chromium hydroxid ($Cr(OH)_3$), aluminum hydroxid ($Al(OH)_3$).*

Pierce the point of the filter and wash the precipitate into a test tube, using as little water as possible. Add potassium or sodium hydroxid and boil a few minutes. If a precipitate remains, filter and wash.

PRECIPITATE: $Fe(OH)_3$ or $Cr(OH)_3$.

For iron dissolve the precipitate in a small quantity of HCl and test the solution $FeCl_3$ for iron with KCNS. If iron is present the original solution must be tested to determine whether it is in the ferrous or ferric condition. (See iron). Remember that some ferric iron will always be present in ferrous solutions which have been exposed to the air.

For chromium test a portion of the precipitate by heating in a crucible or on platinum foil with potassium nitrate and sodium carbonate to change to chromate. Dissolve the potassium or sodium chromate thus formed in water. Add acetic acid ($HC_2H_3O_2$) and test for chromium with lead acetate. (See article on chromium).

NOTE.—When chromium is present it is indicated by a change in color of the original solution from yellow to green when treated with H_2S .

SOLUTION: $K_2Al_2O_4$.

Potassium aluminate. See aluminum.

For aluminum add to the potassium or sodium solution a very small quantity of HCl, just enough to make it acid, then add ammonium carbonate. A precipitate ($Al(OH)_3$) indicates ^{WHITE} aluminum.

See article on aluminum.

FILTRATE: *Class B. May contain zinc, nickel, cobalt or manganese.*

Add ammonium sulfid to the filtrate from Class A, and if a precipitate appears, warm until it settles. Filter and wash. Examine filtrate for the Fourth Group.

PRECIPITATE; ZnS , NiS , CoS , or MnS .

Treat on the filter with cold dilute HCl. Note if a black residue remains. Boil the filtrate to free from ammonium sulfid.

RESIDUE: NiS or CoS , Black.	SOLUTION: $ZnCl_2$ or $MnCl_2$.	
Test by the blow-pipe for nickel or cobalt. (See nickel and cobalt, page 119).	Add an excess of potassium or sodium hydroxid and allow to stand for several minutes without heating. Filter.	
	PRECIPITATE: $Mn(OH)_2$.	SOLUTION: K_2ZnO_3 .
	Oxidize to permanganic acid as described under manganese (page 121). Test by blow-pipe.	Precipitate again with ammonium sulfid. A white precipitate ZnS indicates Zn. Study the reactions given under Zn.

METALS OF GROUP IV.

The metals of this group are Barium, Strontium, and Calcium. They rapidly oxidize on exposure to the air, and so never are found free in nature.

BARIUM.

SYMBOL BA.

ATOMIC WEIGHT 136.

Barium is a silver white metal which is very ductile and malleable. As a metal it is extremely hard to obtain. It occurs in the form of ore, as Heavy Spar, ($BaSO_4$), and as Witherite, ($BaCO_3$).

I. Make a solution of $BaCl_2$ (barium chlorid) in water. Dip into the solution a platinum wire and hold in the colorless flame of the burner. Note color given to flame. What other elements have we studied that have given a like color to the flame?

II. To a small quantity of a barium solution add a few drops of dilute H_2SO_4 . Note precipitate. Write the equation. Where has this reaction been used before? Is $BaSO_4$ soluble in water?

III. Barium solution + $K_2CO_3 = BaCO_3 + ?$ White precipitate.

IV. Barium solution + $K_2CrO_4 = BaCrO_4 + ?$ or
 Barium solution + $K_2Cr_2O_7 = BaCrO_4 + ?$ Yellow precipitate.

STRONTIUM.

SYMBOL SR.

ATOMIC WEIGHT 87.

Strontium occurs in strontianite ($SrCO_3$), and in celestite ($SrSO_4$). It is much like barium, being a white or light yellow metal, malleable and ductile. It never occurs as a metal, however, and is rapidly oxidized.

I. Test a strontium solution with platinum wire. It colors the flame crimson. This is the easiest and most general test for strontium.

II. Test a strontium solution with H_2SO_4 . $SrSO_4$ is precipitated. Try to dissolve in hot water. Is it more or less soluble in water than $BaSO_4$?

CALCIUM.

SYMBOL CA.

ATOMIC WEIGHT 40.

Like barium and strontium, calcium never occurs free. It occurs chiefly in the form of its carbonate in marble, chalk, limestone, etc.; also as a fluorid in fluorspar (CaF_2), as a sulfate in gypsum ($CaSO_4$), as a phosphate in apatite ($Ca_3(PO_4)_2$), etc.

I. Dissolve a piece of marble ($CaCO_3$) in HCl . What gas is generated? What salt is formed? Evaporate nearly to dryness and thus make a very concentrated solution. Add a few drops of H_2SO_4 . Note the precipitate. Is it soluble in water? How does $CaSO_4$ compare with $BaSO_4$ and $SrSO_4$ as to solubility in water?

II. Calcium solution + $KOH = Ca(OH)_2 + ?$
 White precipitate.

III. Precipitate a dilute solution of some calcium salt which contains free ammonia with ammonium oxalate

and allow the white precipitate to stand for several hours. Examine the precipitate with a microscope.

IV. Test a calcium solution with a platinum wire. It colors the flame brick red.

SEPARATIONS OF GROUP IV.

May contain barium, calcium or strontium.

To the filtrate from group III containing ammonium chlorid add ammonium carbonate and hydroxid. Heat gently for some time, then filter.

BaCO_3 , SrCO_3 and CaCO_3 will be precipitated.

Dissolve the well washed precipitate in dilute acetic acid. The solution will contain acetates of barium, calcium and strontium. To a small portion of this solution add potassium dichromate and if a precipitate appears add the reagent till no more precipitate is formed then filter and wash.

PRECIPITATE: BaCrO_4
YELLOW.

Confirm by dissolving this precipitate in HCl and precipitating again with H_2SO_4 . White BaSO_4 is formed. Try also the flame test for barium.

SOLUTION: $\text{Sr}(\text{C}_2\text{H}_3\text{O}_2)_2$ or $\text{Ca}(\text{C}_2\text{H}_3\text{O}_2)_2$.

Precipitate with ammonium carbonate (NH_4)₂ CO_3 with ammonium hydroxid. Filter and wash the precipitate then dissolve once more in dilute acetic acid and divide the solution into two portions.

I. FOR STRONTIUM.

To a portion add a solution of calcium sulfate; boil, allow to stand for a short time and a white precipitate SrSO_4 indicates strontium.

Test by platinum wire in the colorless flame. (See page 107). crimson color is given the flame.

II. FOR CALCIUM.

Add a solution of potassium sulfate and filter to remove all strontium. To the filtrate add NH_4OH and ammonium oxalate $(\text{NH}_4)_2\text{C}_2\text{O}_4$. A precipitate of CaC_2O_4 indicates calcium. This precipitate is insoluble in $\text{HC}_2\text{H}_3\text{O}_2$ but soluble in HCl .

METALS OF GROUP V.

The metals of this group consist of Magnesium, Potassium, Sodium and Ammonium (NH_4). The last, ammonium, is not strictly a metal, but since it acts as such, replacing hydrogen in acids to form salts, etc., it is treated as a metal.

SEPARATIONS OF GROUP V.

I. Evaporate a drop or two of the original solution on a piece of platinum foil at a gentle heat. If a residue is obtained heat strongly and if this residue vaporizes quickly ammonium compounds are indicated.

FOR AMMONIUM.

Take a portion of the original material with potassium or sodium hydroxid and heat gently. The odor of ammonia may be noticed, or, it may be detected by its effect on moistened litmus paper, or, by the effect on a rod dipped in HCl .

Or, conduct the gas into water and add *Nessler's reagent, a brown precipitate of nitrogen dimercuric iodid, HHg_2I is produced.

Test another portion with HgCl_2 . A white precipitate of nitrogen dihydrogen mercuric chlorid is produced. (NH_2HgCl .)

FOR MAGNESIUM.

Test the filtrate from group four.

Add a little ammonium hydroxid then enough ammonium chlorid to dissolve any precipitate which may appear. Now add sodium phosphate and a white precipitate MgNH_4PO_4 indicates magnesium.

If magnesium is present it will prevent the tests for sodium and potassium. So it must be removed. To remove magnesium, precipitate it with barium hydroxid, then remove the barium with sulfuric acid.

FOR POTASSIUM.

Test by the flame on platinum wire.

Violet color is given to the flame which is not hidden by blue glass.

FOR SODIUM.

Test in the flame. Yellow color is imparted to flame.

The color is obscured by blue glass

NOTE.—A sufficient number of pieces of cobalt glass should be placed at convenient points in the laboratory.

NOTE.—*Nessler's reagent is made by adding to a solution of mercuric chlorid a solution of potassium iodid until the precipitate is nearly all redissolved; then add solution of potassium hydroxid. Leave until the liquid becomes clear and use after decantation to free from any remaining sediment.

SUMMARY.
GROUPING OF THE METALS.

I. Add HCl a drop at a time as long as any precipitate is produced. Warm, shake and filter.	
PRECIPITATE. Group I. Lead, $PbCl_2$. <u>WHITE.</u> Silver, $AgCl$. <u>WHITE.</u> Mercury (monad) Hg_2Cl_2 . <u>WHITE.</u> Proceed as on page 95.	
II. To the filtrate, or, if group I. is absent to the origin solution + HCl add hydrogen sulfid until the solution smells strongly of the gas. Warm and filter.	
PRECIPITATE. Group II. Arsenic, As_2S_3 . <u>YELLOW.</u> Antimony, Sb_2S_3 . <u>ORANGE.</u> Tin, SnS . <u>BROWN.</u> Lead, PbS . <u>BLACK.</u> Bismuth, Bi_2S_3 . <u>BLACK.</u> Copper, CuS . <u>BLACK.</u> Cadmium, CdS . <u>YELLOW.</u> Mercury, HgS . <u>BLACK.</u> Changes from white and yellow to black.	
III. Boil to expel excess of H_2S . Proceed by pages 125, 127. PRECIPITATE. Group III. A. By ammonium hydroxid and ammonium chlorid. Aluminum, $Al(OH)_3$. <u>WHITE.</u> Jelly like. Chromium, $Cr(OH)_3$. <u>BLUE GREEN.</u> Iron, $Fe(OH)_3$. <u>BROWN.</u>	
B. By ammonium sulfid. Manganese, MnS . <u>PINK.</u> Cobalt, CoS . <u>BLACK.</u> Nickel, NiS . <u>BLACK.</u> Zinc, ZnS . <u>WHITE.</u>	
IV. To the filtrate from group III. containing NH_4OH and NH_4Cl add $(NH_4)_2CO_3$ and NH_4OH . Heat gently for some time. Do not boil. Filter. PRECIPITATE. Group IV. Barium, $BaCO_3$. <u>WHITE.</u> Strontium, $SrCO_3$. <u>WHITE.</u> Calcium, $CaCO_3$. <u>WHITE.</u>	

TESTING FOR ACIDS.

Before testing, all the metals which would interfere may be removed by treating the unknown with a concentrated solution of potassium or sodium carbonate.

To a small quantity of the solid substance of the unknown or to a concentrated solution of the same add a little concentrated H_2SO_4 and heat gently. If the vapor reddens moist litmus paper some of the following acids may be present.

I. If there is effervescence, CO_2 is indicated and a carbonate is probably present.

II. If the gas has an odor it may be:

a. H_2S has odor of rotten eggs, and blackens paper moistened with lead acetate.

b. SO_2 , sulfurous anhydrid. Odor of burning sulfur.

c. $\text{H}(\text{C}_2\text{H}_3\text{O}_2)$, odor of vinegar. Gives a red solution with ferric chlorid.

d. HCl , slight sharp odor. Forms a white cloud when brought in a contact with ammonia vapor.

III. Gases having color:

a. HI . Hydriodic acid. Violet color. Colors CS_2 blue or violet. See page 15.

b. HBr . Hydrobromic acid. Brown color. Test with CS_2 . See page 15.

IV. HClO_3 . Chloric acid. Explodes when substance is brought in contact with H_2SO_4 . Has odor of chlorin.

V. For nitric acid try the brown ring test. See page 53.

VI. For sulfuric acid and sulfates, precipitate the original solutions with BaCl_2 . BaSO_4 of a white color is formed.

Chlorin is sometimes evolved when hypochlorites, bleaching powder, etc., are present in the unknown.

SOLUTION.

I. Add to a test tubeful of hot water as much salt as it will dissolve. Allow to cool slowly and note the crystals formed.

Repeat with copper sulfate, potassium chlorate. Examine the crystals with a microscope or good magnifier. Determine the system of crystallization if possible, referring to any work on mineralogy.

II. Determine the temperature of twenty cc. distilled water. Add a quantity of common salt, stir and again note the temperature. Try the same with sodium nitrate (NaNO_3) copper sulfate, etc.

III. To a small quantity of water in a test tube gradually add concentrated sulfuric acid and note changes in temperature. Do you see why we should be careful in diluting concentrated sulfuric acid?

IV. In a small quantity of water in an evaporating dish place a small piece of potassium or sodium hydroxid, determining the the temperature change.

SOLUTION OF METALS, THEIR OXIDS AND HYDROXIDS IN ACIDS.

I. Dissolve a small piece of zinc in dilute hydrochloric acid. What gas is generated? Write the equations. Evaporate nearly to dryness, then take a drop of the solution, place on a microscope slide and allow to evaporate to dryness without further heating. This brings about the formation of good crystals.

Repeat same with iron filings, with magnesium wire.

Repeat with copper. What gas is formed? Why not hydrogen?

II. Repeat the above with zinc oxid, ferric oxid, magnesium oxid, and calcium oxid. What gas has been formed?

III. Repeat with the hydroxids of the above metals. Evaporate the various solutions to dryness, examine with the microscope and determine whether the salts formed are the same as when metals or their oxids are dissolved. Write out all the equations connected with these three experiments.

IV. Repeat the three above experiments with sulfuric acid instead of hydrochloric. Write all the equations.

NOTE.—Dilute the acid for this experiment, using one part of concentrated acid to nine of water.

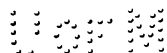
WATER OF CRYSTALLIZATION.

I. Dry some crystals of common salt on filter paper and heat in a dry test tube. Is any water given off? Try the same with crystals of copper sulfate, with sodium sulfate, with zinc sulfate. How do these latter substances differ from common salt?

To the dry copper sulfate after cooling add a little water. Note change in color. Note change in temperature.

II. EFFLORESCENCE.—On three separate watch crystals place small crystals of, (a) sodium carbonate, (b) sodium sulfate, and (c) copper sulfate. Let them stand over night and note changes.

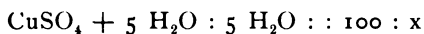
III. Repeat II, using calcium chlorid and potassium and sodium hydroxids.





DETERMINATION OF WATER OF CRYSTALLIZATION.

I. CuSO_4 . Clean out very carefully a small porcelain crucible, dry, cool and weigh very exactly on a good pair of balances. Handle the crucible with a pair of pincers, as touching it with the fingers will make a variation in the results. Select a good clean crystal of copper sulfate weighing about two grams and place in the crucible. Weigh again the crucible + the copper sulfate. Of course the difference will be the exact weight of the sulfate. Place in an air bath and heat to 225° for an hour. At the end of the time place in a desiccator and allow to cool, then weigh again. The loss in weight represents the weight of water in copper sulfate. Calculate the per cent. of water thus, copper sulfate crystallizes with five molecules of water:



where x = the wished per cent.

$$64 + 32 + 64 + 90 : 90 :: 100 : x$$

$$x = 36 \text{ per cent.}$$

Calculate in the same way, placing the actual weight of the crystal in the place of $\text{CuSO}_4 + 5 \text{H}_2\text{O}$ and the weight of water for $5 \text{H}_2\text{O}$. Repeat the experiment several times till you can get *accurate* results.

NOTE.—Often a failure arises from heating too short a time, thus not freeing from water completely.

II. Repeat the above with barium chlorid $\text{BaCl}_2 + 2 \text{H}_2\text{O}$, heating to a temperature of $125\text{--}150^\circ$.

III. a. Heat two or three grams of gypsum ($\text{CaSO}_4 + 2 \text{H}_2\text{O}$) in a hot air bath to about 105° , until it will break up into a fine powder. You now have plaster of Paris. Make into a paste and watch it, "set."

b. Heat about three grams of gypsum, which has been carefully weighed, in an air bath to about 250° (from 220 – 250°) for an hour. Remove from the air bath, cool in a desiccator, and weigh again. Determine the per cent. of water of crystallization, assuming gypsum to have the formula $\text{CaSO}_4 + 2 \text{H}_2\text{O}$. Compute as in the case of copper sulfate. Compute theoretical results and compare with your results. If the per cent. is too low it is quite probable that you must heat more to drive out the water.

NOTE.—It is quite necessary that every laboratory should have one good pair of balances. The instructor should give each student a lesson in weighing before any attempt is made to do quantitative work.

ULTIMATE ANALYSIS OF BARIUM CHLORID

WATER OF CRYSTALLIZATION.

I. Weigh out very carefully about two grams of barium chlorid and determine its water of crystallization as described before. Compute.

BARIUM.

II. Now weigh a clean small watch glass and record its weight. Next place about one gram of BaCl_2 on the glass and weigh again. Record the weight of the chlorid. Next wash it very carefully into a clean beaker and dissolve in distilled water. Heat almost to boiling, then precipitate the barium as barium sulfate with dilute sulfuric acid (one part concentrated acid to nine of water), stirring the solution with a glass rod during the precipitation. Heat for a minute or two, constantly stirring, then filter and wash with hot water. Be careful not to spill a single bit of the precipitate, as the least carelessness will make

great errors. When the precipitate is washed transfer the filter paper containing it to a crucible which has been carefully weighed. Always handle crucibles with pincers. Heat the crucible gently until the paper and precipitate are perfectly dry, then heat more strongly until both are reduced to a clean white powder. Cool in a desiccator and weigh. Tabulate your results and compute as follows:

EXAMPLE.

Weight of watch glass + (BaCl ₂ + 2H ₂ O)	= 3.1075 grams.
“ “ “ “ (empty)	= 2.1098 “
“ “ BaCl ₂ + 2H ₂ O	= 0.9977 “
“ “ crucible + BaSO ₄	= 9.2811 “
“ “ empty crucible	= 8.3302 “
“ “ BaSO ₄	= 0.9509 “
Per cent. of barium as calculated	= 56.14
“ “ “ “ found	= 56.04
Error	= 0.10

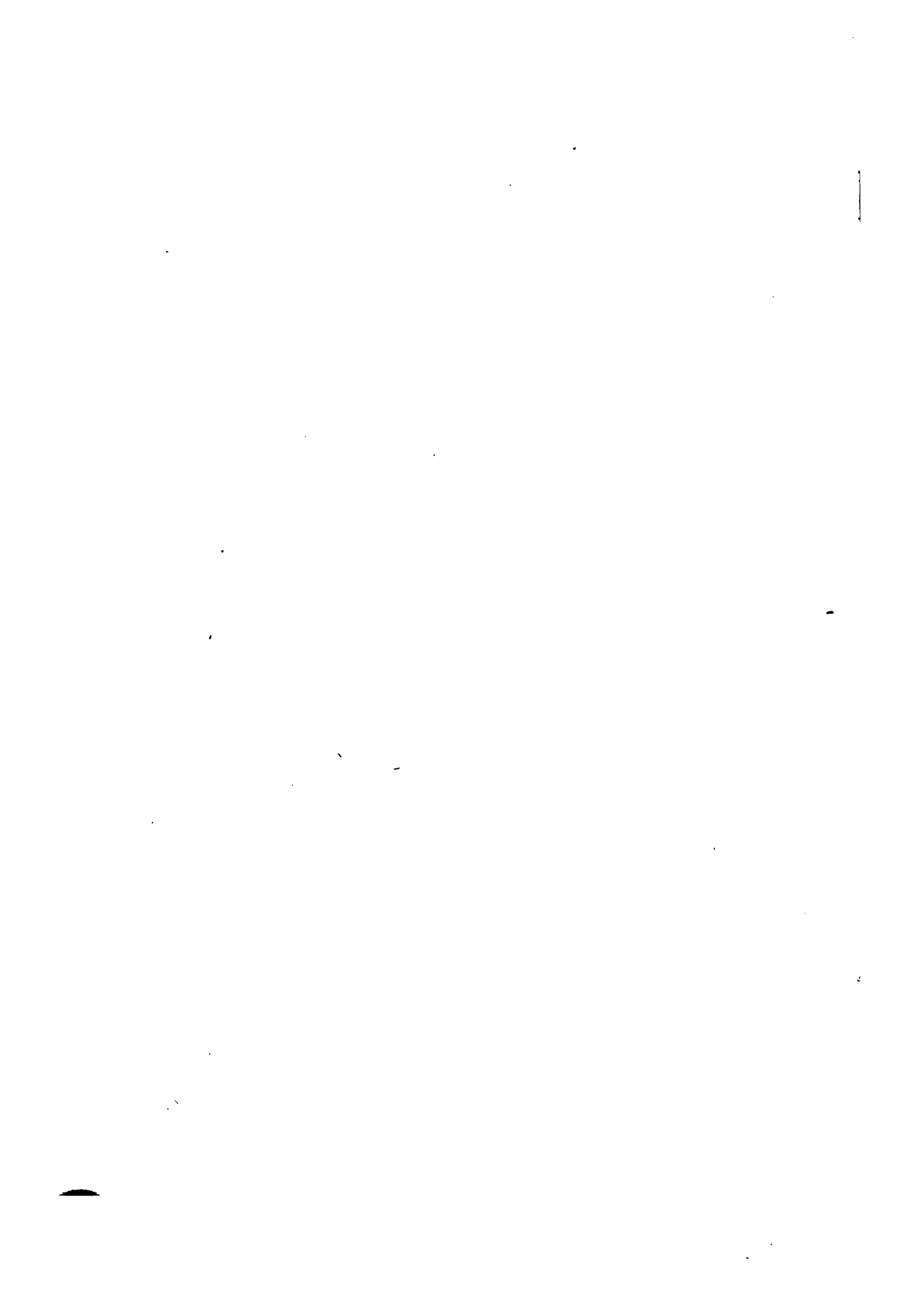
COMPUTATIONS. (*Theoretical.*)

The molecular weight of BaCl₂ + 2H₂O : the atomic weight of Ba :: 100 : x or 244 : 137 :: 100 : x where x = the per cent of Ba.

BaSO₄ : Ba :: .9509 : x, x = the actual weight of Ba in .9509 grams of BaSO₄ = .5590 grams; then the weight of BaCl₂ + 2H₂O : Ba :: 100 : y, where y = % Ba, or 0.9977 : .5590 :: 100 : y. y = 56.04.

CHLORIN.

III. Weigh out about one gram of BaCl₂ + 2H₂O very carefully, as before. Wash into a clean beaker and dissolve in water. Heat and while hot precipitate the chlorin with silver nitrate. Silver chlorid is formed. Continue heating until the precipitate settles to the bottom



of the beaker. Filter and wash carefully with hot water. Place the filter paper and precipitate in a weighed crucible and allow to stand in a drying oven at 115° until perfectly dry. Now heat directly in a burner flame until the silver chlorid just begins to melt. Cool and weigh then compute the per cent of chlorin in $\text{BaCl}_2 + 2\text{H}_2\text{O}$.

EXAMPLE.

Watch glass + $(\text{BaCl}_2 + 2\text{H}_2\text{O})$	= 3.0036	grams.
“ “ empty	= 2.1103	“
Weight of $(\text{BaCl}_2 + 2\text{H}_2\text{O})$	= 0.8933	“
“ “ crucible + AgCl	= 8.3486	“
“ “ empty crucible	= 7.3187	“
“ “ AgCl	= 1.0299	“
Per cent. of chlorin calculated	= 29.10	“
“ “ “ found	= 28.69	“
Error	= 0.41	“

Theoretical.— $\text{BaCl}_2 + 2\text{H}_2\text{O} : \text{Cl}_2 :: 100 : x$, where $x = \% \text{ Cl}$. $244 : 71 :: 100 : x$; $x = 29.10$.

FOUND.— $\text{AgCl} : \text{Cl} :: 1.0299 : x$. $x = \text{actual weight Cl in } 1.0299 \text{ grams AgCl}$.

$143 : 35.5 :: 1.0299 : x$. $x = .2556 \text{ grams Cl in } 1.0299 \text{ grams AgCl}$.

$\text{BaCl}_2 + 2\text{H}_2\text{O} : \text{Cl}_2 :: 100 : y$

$0.8933 : .2556 :: 100 : y$. $y = 28.69$.

To determine whether your results are correct, add the per cent of Cl, Ba, and H_2O and they should equal 100%.

SODIUM CHLORID.

Determine the amount of Cl in sodium chlorid following the above methods for chlorin.

COPPER SULFATE ($\text{CuSO}_4 + 5 \text{H}_2\text{O}$).

I. Determine the water of crystallization of CuSO_4 .

Note.—If this has been done correctly once before, the results of the first determination may be used.

II. Weigh out a crystal carefully, dissolve in water, heat and precipitate with barium chlorid. BaSO_4 will be formed. Dry and heat until reduced to a clean white powder. Weigh and calculate the SO_4 in $\text{CuSO}_4 + 5\text{H}_2\text{O}$. Tabulate results.

III. In the following experiment it is best to use a Rose crucible, *i. e.* one which is fitted with a cover and a porcelain delivery tube.

Weigh out a clean copper sulfate crystal. Heat gently to about 250° until all the water of crystallization is driven off. Then heat more strongly directly in the flame of a burner until the copper sulfate is changed to copper oxid, allowing a slow current of oxygen to pass into the crucible during the heating.

Calculate the amount of copper and add up your results to make 100%.

SILVER NITRATE.

Determine the amount of silver in a weighed sample of silver nitrate, using dilute hydrochloric acid to precipitate the silver. The process is a reversal of that already given for chlorin and the student will have no difficulty in following it.

DEFINITIONS.

I. **Acid.**—An acid may be defined as a compound of hydrogen and a non-metal usually in combination with oxygen. The acids containing oxygen are called oxacids. Examples are HNO_3 , H_2SO_4 , H_3PO_4 , HClO_3 , etc. An acid has a sour taste, reddens certain vegetable coloring mat-

187

187

ters such as litmus, and contains hydrogen which may be replaced by a metal.

II. **Non-metals.**—The non-metals which form acids are the halogens, sulfur, phosphorus, nitrogen, arsenic, etc.

III. **Salt.**—A salt is a compound in which the hydrogen of an acid has been replaced by a metal. As KNO_3 , K_2SO_4 , NaCl , etc.

IV. **Base.**—A base is an oxid or hydroxid of a metal. Bases dissolve in acids to form salts and water. As $\text{KOH} + \text{HCl} = \text{KCl} + \text{H}_2\text{O}$, etc.

Metals act like bases in some cases because they dissolve in acids to form salts, forming hydrogen instead of water. As $\text{Zn} + 2 \text{HCl} = \text{ZnCl}_2 + 2 \text{H}$, etc.

NOTE.—When a metal is treated with an acid, hydrogen is set free, but in many cases such as the solution of copper in sulfuric acid, or of any metal in nitric acid, the nascent hydrogen has a secondary action on the acid, and reduces it to form sulfur dioxid or nitric oxid, so that, although hydrogen is set free, it is disguised by the secondary products and is not the ultimate product of the reaction.

V. **An alkali** is a base that is soluble in water and turns litmus paper blue. As KOH , NH_4OH , etc.

VI. **An anhydrid** is a body which when combined with water will form an acid. As SO_2 , SO_3 , B_2O_3 , As_2O_3 , etc.

Oxacids whose names end in *ic* form salts ending in *ate*, while those containing less oxygen whose names end in *ous* form salts whose names end in *ite*. In general when a metal forms two classes of salts, those having a less amount of oxygen have names ending in *ous*, while the names of those having more oxygen end in *ic*. Examples are mercurous, mercuric, ferrous, ferric, etc., for adjectives, and mercurousum, mercuricum, etc., for nouns.

**NUMBER OF GRAMS OF SOLIDS TO 500 cc.
OF H₂O.**

AgNO ₃ *	25	KCN	50	Na ₂ CO ₃	50
BaCl ₂	50	KCl	25	NaOH	60
C ₁₂ H ₂₂ O ₁₁	sat	K ₂ CrO ₄	25	NH ₄ Cl	60
CaCl ₂	50	K ₂ Cr ₂ O ₇	25	(NH ₄) ₂ CO ₃	125
Ca(OH) ₂	sat	K ₃ Fe(CN) ₆	40	(NH ₄) ₂ C ₂ O ₄	20
CuCl ₂	25	K ₄ Fe(CN) ₆	40	NH ₄ NO ₃	50
Cu(NO ₃) ₂	25	KI	25	(NH ₄) ₂ SO ₄	5
FeCl ₃	25	KNO ₂	50	Pb(C ₂ H ₃ O ₂) ₂	50
FeSO ₄ *	50	KNO ₃	50	PbCl ₂	sat
HNaCO ₃	50	KOH	60	Pb(NO ₃) ₂	50
HNaPO ₄	50	MgCl ₂	50	SnCl ₂	40
HgCl ₂	25	MgSO ₄	50	SrCl ₂	50
HgNO ₃ *	25	MnCl ₂	25	ZnCl ₂	25
KBr	25	NaCl	50		

Acid.—Whether concentrated, or dilute acids are to be used depends upon the kind of work in hand. The instructor should direct the pupil in this matter.

REFERENCE BOOKS.

Venable. "History of Chemistry," 1894. 172 pages, \$1.00. D. C. Heath & Co., Boston.

Remsen. "Inorganic Chemistry," advanced course, 1889. 827 pages, \$2.80. Henry Holt & Co., N. Y.

Freer. "General Inorganic Chemistry," 1895. 550 pages, \$3.00. Allyn & Bacon, Boston.

Roscoe & Schorlemmer. "Treatise on Chemistry," Vols. I and II, 1892. \$11.00. D. Appleton & Co., N. Y.

Remsen. "Theoretical Chemistry," 1892. 326 pages. \$2.00. Lea Brothers & Co., Philadelphia.

Prescott & Johnson. "Qualitative Analysis," 1891. 317 pages, \$3.50. D. Van Nostrand Co., N. Y.

Mixer. "Text-Book of Chemistry," 1896. 441 pages. \$1.50. Jno. Wiley & Sons, N. Y.

* Do not filter AgNO₃, nor bring it in contact with organic matter. Ferrous sulphate should be prepared as needed. Make a mixture of 475 cc. of H₂O and 25 cc. of HNO₃ in preparing HgNO₃.

INDEX.

	PAGE
Aqua Regia	93
Arsenic	97
Antimony	101
Ammonia	47
Arsin	99
Aluminum	117
Acids (quantitative tests for)	137
Bromin	13
Brown Ring Test for Nitrates	53
Boron	71
Barium	127
Carbon	59
Carbon Dioxid	61
Chlorin	9
Compounds of Halogens With Hydrogen	17
Compounds of Nitrogen With Hydrogen	47
Copper	105
Cadmium	107
Chromium	115
Cobalt	119
Calcium	129
Definitions	151
Distinction Between Ferrous and Ferric Compounds	115
Elements	V
Electrolysis Apparatus	29
Ethylene	65
Ethene	65
Flame	73

Grouping of the Metals	83
Hydrogen	1
Halogens	9
Hydrochloric Acid	17
Hydriodic Acid	23
Hydrofluoric Acid	23
Hydrogen Sulfid	37
Iodin	15
Iron	113
Kipp's Apparatus	39
Lead	85
Metals of Group V	133
Manganese	121
Marsh's Test	97
Metals	79
Mercury	91
Nitrous Oxid	55
Nitric Oxid	55
Nitrogen	45
Nitric Acid	49
Nitrohydrochloric Acid	93
Nickel	119
Oxygen	25
Oxids of Nitrogen	55
Phosphorus	57
Principles	79
Quantitative Analysis of Barium Chlorid	145
Quantitative Analysis of Copper Sulfate	151
Separation of First Group Metals	93
Sugar	67
Silver	89
Stibin	101
Separation of Second Group Metals	107

INDEX.

159

Strontium	129
Separation of Third Group Metals	123
Solution	139
Separation of Fourth Group Metals	131
Separation of Fifth Group Metals	133
Sulfur	33
Sulfuric Acid	41
Tin	101
Water	29
Water of Crystallization	141
Zinc	123

PUBLICATIONS
OF

GEORGE WAHR,

Publisher and Bookseller,

ANN ARBOR, MICH.

A Text-Book of Elementary Mechanical Drawing for use in Office or School.—By Clarence G. Wrentmore, B. S., C. E., and Herbert J. Goulding, B. S., M. E., *Instructors in Descriptive Geometry and Drawing* at the University of Michigan. Quarto, 109 pages, \$1.00.

Plain Alphabets for Office and School.—Selected by C. G. Wrentmore, B. S., C. E., *Instructor in Descriptive Geometry and Drawing*, University of Michigan. Pamphlet, 50 cents.

Tables for the Calculation of Simple or Compound Interest and Discount and the Averaging of Accounts. The Values of Annuities, Leases, Interest in Estates and the Accumulations and Values of Investments at Simple or Compound Interest for all Rates and Periods, also Tables for the Conversion of Securities and the Value of Stocks and Bonds. With full Explanation for Use.—By James C. Watson, Ph. D., LL. D. Quarto. Cloth, \$2.50.

A Handbook of Practical Astronomy for University Students and Engineers.—By W. W. Campbell, Sometime Instructor in the University of Michigan, *Astronomer* in the Lick Observatory. 12 mo. 166 pages. \$1.25.

The Theory of Substitutions and its Application to Algebra.—By Dr. Eugene Netto, *Professor of Mathematics* in the University of Giessen. Revised by the author and translated with his permission, by F. N. Cole, Ph. D., formerly Assistant Professor of Mathematics in the University of Michigan, *Professor of Mathematics* in Columbia University. 8 vo. 301 pages. Cloth, \$3.00.

Mathematical Theories of Planetary Motions.—By Dr. Otto Dzlobek, *Privatdocent in the Royal Technical High School of Berlin, Charlottenburg*. Translated by Mark W. Harrington—formerly Chief of the United States Weather Bureau, and, Professor of Astronomy and Director of the Observatory at the University of Michigan, President of the University of Washington, and Wm. J. Hussey, *Assistant Professor of Astronomy* in the Leland Stanford, Junior, University. 8 vo. 294 pages. \$3.50.

A French Reader for Beginners, with Notes and Vocabulary.—By Moritz Levi, *Assistant Professor of French*, University of Michigan, and Victor E. Francois, *Instructor in French*, University of Michigan. 12 mo. 261 pages. \$1.00.

Les Aventures Du Dernier Abencerage Par Chateaubriand, Edited with Notes and Vocabulary.—By Victor E. Francois, *Instructor in French* in the University of Michigan. Pamphlet, 35c.

Brief Outlines in European History. A Syllabus for the Use of Students in the University of Michigan.—By Earl Wilbur Dow. Two parts each. 41 pages. Pamphlet, 35 cents.

The Study of Ethics. A Syllabus.—By John Dewey, *Professor of Philosophy* in the University of Chicago. Octavo. 144 pages. Cloth, \$1.25.

Practical Pathology for Students and Physicians. A Manual of Laboratory and Post-Mortem Technic, Designed Especially for the Use of Junior and Senior Students in Pathology at the University of Michigan.—By Aldred Scott Warthin, Ph. D., M. D. *Instructor in Pathology*, University of Michigan. Octavo. 234 pages. Cloth, \$1.50.

Directions for Work in the Histological Laboratory.—By G. Carl Huber, M. D., *Assistant Professor of Histology and Embryology*, University of Michigan. Second edition, revised and enlarged. Octavo. 191 pages. Cloth, \$1.50.

Directions for Laboratory Work in Bacteriology.—By Frederick G. Novy, Sc. D., M. D., *Junior Professor of Hygiene and Physiological Chemistry*, University of Michigan. Octavo. 209 pages. Cloth, \$1.50.

Directions for Laboratory Work in Urine Analysis.—By Frederick G. Novy, Sc. D., M. D., *Junior Professor of Hygiene and Physiological Chemistry*, University of Michigan. Octavo. 102 pages. Cloth, \$1.35.

Directions for Laboratory Work in Physiology for the Use of Medical Classes.—By W. H. Howell, Ph. D., M. D., *Professor of Physiology and Histology*. Pamphlet, 62 pages, 65 cents.

Select Methods in Inorganic Quantitative Analysis.—By Byron W. Cheever, A. M., M. D. Revised and enlarged by Frank Clemes Smith. Third edition. 12 mo. \$1.75.

Syllabus of Lectures on Pharmacology and Therapeutics in the University of Michigan. Arranged Especially for the Use of the Classes. Taking the Work in Pharmacology and Therapeutics at the University of Michigan.—By S. A. Matthews, M. D., *Assistant in Pharmacy and Therapeutics*, University of Michigan. 12 mo., 114 pages. \$1.50.

Algebra—By Elmer A. Lyman, A. B., Edwin C. Goddard, Ph. B., and Arthur G. Hall, B. S., *Instructors in Mathematics*, University of Michigan. Octavo. 75 pages. Cloth, 90 cents.

Laboratory Manual of Elementary Chemistry.—By Jabez Montgomery, Ph. D., *Professor of Natural Science* in the Ann Arbor High School, and Roy B. Smith, *Assistant Professor in Chemical Laboratory*, Ann Arbor High School. 12 mo. 150 pages. Cloth, \$1.00.

The Cranial Nerves. 12 pairs. By C. L. Ford, M. D., *Late Professor of Anatomy and Physiology* in University of Michigan. (Chart) 25 cents.

Classification of the Most Important Muscles of the Human Body, With Origin Insertion, Nervous Supply and Principal Action of Each.—By C. L. Ford, M. D., *Late Professor of Anatomy and Physiology* in the University of Michigan. Chart 50 cents.

Cronological Outline of Roman Literature.—By C. L. Meader, A. B., *Instructor in Latin* in University of Michigan. (Chart) 25 cents.

Outline of Anatomy. A Guide to the Dissection of the Human Body, Based on Gray's Anatomy.—54 pages. Boards. 60 cents.

Any of the above named books sent (post paid) on receipt of price.
GEORGE WAHR, Publisher and Bookseller, Ann Arbor, Mich.

